GOVERNMENT OF NEW BRUNSWICK

GOUVERNEMENT DU NOUVEAU-BRUNSWICK

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GOVERNMENT OF CANADA
REGIONAL INDUSTRIAL EXPANSION

GOUVERNEMENT DU CANADA
EXPANSION INDUSTRIELLE REGIONALE

The World Market for Chitin and Chitosan and Implications for New Brunswick

Prepared by
THE DPA GROUP INC.

FINAL REPORT

THE WORLD MARKET FOR CHITIN AND CHITOSAN AND IMPLICATIONS FOR NEW BRUNSWICK

Prepared for:

New Brunswick Department of Commerce & Technology

and

Department of Regional Industrial Expansion

Prepared by:

The DPA Group Inc.

FREDERICTON, New Brunswick

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EXECUTIVE SUMMARY

PRODUCTION AND PRODUCERS

1. Chitin is one of the world's most abundant natural polymers. It is found in many plants and animals, but one of its most common sources is in crab shells, and it can be extracted from the waste of the crab processing industry.

2. Chitosan is a related product, made from the deacetylation of chitin. It contains a lower level of nitrogen and has a positive charge.

3. Despite a high level of interest and research and development chitin has actually found few commercial uses. It is more expensive to produce than synthetic polymers and limited raw material supply have prevented extensive market penetration.

4. World production is estimated to be just slightly over 1000 tonnes, of which 90% is produced in Japan and the remainder more or less evenly divided among the U.S., Europe and the rest of the world.

5. Production capacity worldwide today is approximately double the actual level of production. It is believed that lack of raw material is partly responsible for the low volume of production, but the main deterrent is a lack of any significant market for chitin at the selling price needed to cover costs of manufacturing.

6. Producers tend to be either primary producers, who make chitin from the shellfish waste, or secondary producers who make other products from chitin. Ordinarily, producers make either primary or secondary products, however, Protan, of Redmond, Washington has recently

established a secondary processing facility. Protan is the only active primary producer in North America.

7. World market share by producer is estimated to be as follows:

Kyowa Oil and Fats (Japan)	30-40%
Kattakura Company (Japan)	30-40%
Protan (USA)	5-10%
Kalaallit Tunisassiorfiat, Greeland	3-5%
Marine Fisheries Institute, Poland	<1%
Other Japanese Producers	5-10%
Other World Producers	5-10%

8. There is also a growing number of new firms being set up to develop new products and processing methods. Many of these have started in the last three years.

PRODUCTS

9. There are five properties of chitin which make it attractive for many uses:

- its high charge density
- its film forming properties
- it induces coagulation
- it has strong binding properties
- it promotes wound healing.

10. There are five applications of chitin in current use:

- waste water treatment
- growth enhancing seed coating
- a nematodicide sold under the brand name "Clandosan"
- clarifying beverages
- hair products.

11. There are five applications we believe will be in use in the next two years:

- surgical sutures
- wound dressings
- topical ointments
- fruit and vegetable preservatives
- fungicide coating for seed.

12. There are another eight products which have a good probability of being on the market in the next five years:

- contact lenses
- protein recovery
- animal feed
- cholesterol reduction
- sustained drug release
- texture control in foods
- fibre additive
- production of amino sugars.

13. There are possibly as many as a hundred products which have longer term development potential. These range from additives for strengthening paper to leather tanning.

THE MARKET

14. Every chitin product and application has different characteristics. There is no common product which will meet many different applications.

15. There are three main barriers to greater penetration of the market:

- the high cost of chitin relative to completing synthetic polymers;

- difficulties in ensuring a consistent quality and adequate quantity of waste materials;

- regulatory barriers against the use of chitin in applications involving human consumption because of lack of knowledge about how humans metabolize chitin. This is changing as the frequency and number of clinical trials increases.

16. The three main market segments tend to group products by their level of purity and other quality characteristics. We have, somewhat arbitrarily, labelled these segments:

    . low grade (water treatment, animal feed);
    . high grade (shampoo, seed coating);
    . ultra-high grade (surgical sutures, dressings, ointments).

    The products are less generic and more application-specific as one moves up the spectrum from low to ultra-high grade.

17. The main specifications required by purchasers of chitin include ranges of:

    . molecular weight;
    . deacetylation level;
    . purity.

    Different products will specify different ranges for each characteristic.

18. Prices increase with increasing quality levels. Chitin for water treatment sells for around $3.50 per pound. For high grade medical applications, the price is between $20 and $50 per pound.

18. The world market is potentially many times greater than the existing level of sales would suggest. For waste

treatment alone, the market is easily in the hundreds of thousands of tonnes. Penetration of this market to any significant degree will require a production process which can make the material at a competitive price. Most contacts believe this is virtually impossible due to the costs of chemicals and energy used in the process. However, a lot of research is focussing on cost of production issue.

20. It is more likely that a number of smaller opportunities will develop for products where price is less important. For example, there is virtually no competition for artificial skin or surgical sutures with the characteristics of chitin. Price will not be a major factor in penetrating this market.

21. We forecast a fairly slow growth in the market for the next five years. Under optimistic conditions (several new breakthroughs, lowered costs of production) the market could grow by 40% per year. Under a "pessimistic" scenario, growth will not exceed 8%. Realistically, we would predict growth in the range of 10-20% for the next five years.

22. After five years, we believe very rapid expansion of the industry is likely. By then, many new high-volume applications will be on the market, more R & D should reduce cost of production and the concerns about human health effects should have been laid to rest (presumably with positive results if all the animal research proves to be correct).

23. Forecasts of demand by region to 1992 under "Pessimistic" and "Optimistic" scenarios range from 1375 tonnes to 3105 tonnes. By region these forecasts are as follows:

	Pessimistic		Optimistic	
	Tonnes	%	Tonnes	%
Japan	1090	79	2088	67
North America	200	15	692	22
Europe	75	5	305	10
Other	10	1	20	1

IMPLICATIONS FOR NEW BRUNSWICK

24. It is generally felt that the quality of the crab waste resource in New Brunswick is more suited to low and high grade applications. Ultra-high grade chitin would not appear to be a realistic product for a New Brunswick producer.

25. The quantity of resource available (roughly 250-300 tonnes) would suggest that high volume production is not possible. Thus, the most realistic approach suggested for New Brunswick (assuming all other barriers can be overcome) is to identify specific high grade applications and produce for these specific markets.

26. There has been a lot of interest in joint venturing with New Brunswick firms by outside companies. We identify seven such companies in the report.

27. Finally, we examine four possible market entry strategies for a new producer. We believe that the most viable strategy would be forming a joint venture with one of the companies identified in the report. The joint-venture partner should have a market-ready product and/or established market network. A New Brunswick firm would undertake pilot-scale manufacturing to determine the quality potential of the product and the ability to produce at a competitive price. Arrangements with crab processors for

transportation and storage of waste will be needed to ensure an adequate supply.

1.0 INTRODUCTION

For several years, crab processors and experts in the uses of waste products from the seafood processing industry, have viewed the possibility of manufacturing chitin and chitosan as an appropriate use of the large volumes of crab waste in New Brunswick. Disposal of the waste is both costly and environmentally sensitive. Reducing this raw material to usable by-products is obviously an attractive idea from numerous perspectives: creating additional value-adding activity, reducing pollution and creating jobs.

The New Brunswick Department of Commerce and Technology and the federal Department of Regional Industrial Expansion decided to commission a study of the market for chitin and chitosan and their derivative products as a preliminary step in developing a strategy to deal with this opportunity.

The DPA Group's Fredericton office was asked to undertake the study and report on the market situation.

The study has been designed as a broad overview of the market. In fact, chitin has many potential uses, and the product characteristics required for each use vary considerably. Our mandate was not to conduct a detailed assessment for any particular market opportunity but rather to assess generally the prospects for producers interested in the possibility of chitin manufacturing.

1.1 Study Objectives

The objectives of the study, as identified by the Steering Committee included the following:

- Obtain the current and future demand for chitin and chitosan by application, user and country.

- Identify existing and emerging trends in chitin and chitosan use and any barriers to enty into these markets.

- Are there any complementary products?

- Obtain user product specifications for each application, potential volume usage and projected growth.

- Identify current producers of chitin and chitosan, their location and existing market share and source of raw materials.

- Identify current distribution patterns and analyze pricing structure.

1.2 Methodology

The current and potential uses of chitin and chitosan were identified from a review of the academic literature, trade journals, and various magazine articles reporting on the product.

The project team's chitin specialist also identified several key researchers and academics conducting work on this product.

Data was collected from the sources identified by an extensive program of telephone interviews. In total, over 100 telephone interviews were conducted. Interviews followed an open-ended structure primarily aimed at gaining a good understanding of the industry and the current level of activity.

As information was collected on specific applications, judgments were made about those which appeared to be the most likely to achieve commercialization over the next ten years. For each of these applications, more extensive follow-ups were made to obtain information concerning market potential, regulatory and pricing

uses and the key players (producers researchers, distributors and competitors).

A list of the individuals contacted during the study appears in Appendix A.

In the final phase of the study, the findings were synthesized to produce an overall description of the market and the implications for a market development strategy.

We have been guided throughout the study by a Steering Committee composed of:

Mr. Maurice Bernier - Commerce & Technology
Mr. Wayne Gunter - DRIE
Ms. Patricia MacKenzie - Commerce & Technology.

We acknowledge the support and help provided by the Steering Committee throughout the course of the study.

1.3 A Word about Terminology

Throughout the report there is a tendency to use the word **chitin** to refer to both chitin and chitosan. In fact the two products are different (chitosan is a more refined form of chitin and has a positive charge). A producer interested in this general field would, however, normally consider the full range of possible products from chitin and chitosan. Use of the single word is intended to simplify the discussion, not in any way limit the range of products.

1.4 Organization of the Report

We begin the descriptive part of the report by providing information about chitin, the processes used to make it and the people and firms involved in the industry and product development.

In the third chapter, we describe the sixteen main chitin products which, in our opinion, have the greatest likelihood of commercialization during the next ten years. This chapter includes a discussion of opportunities, barriers to development and information on the technical aspects of each product.

Chapter 4 describes the world market for chitin. We begin with a recap of the total present market by country and application. This is followed with a discussion of the short-to-medium term market potential by product under both optimistic and pessimistic scenarios. General indicative level estimates are also provided for the long term (5 - 10 year) potential.

Chapter 5 discusses the implications of our findings and market estimates for New Brunswick. We provide an assessment of raw material quality and supply. As a very high level of interest was expressed in the possibilities for joint ventures in New Brunswick, we report on the firms indicating this interest. Finally, we discuss possible strategies for entry into this market for a New Brunswick-based firm.

2.0 CHITIN PRODUCTION AND SUPPLIERS

Chitin, the world's second most abundant polymer, has been the subject of extensive research for the past forty years. In the late 1930s and 1940s intensive interest in the material resulted in nearly fifty patents being established for processes and applications. However, an inadequate raw material supply and high processing cost have always made the chemical uncompetitive with synthetic polymers.

Chitin is a white solid, generally possessing some degree of crystallinity. Differences in the complex structures of the different species and tissues in which it is found result in differences in chain length, crystallinity and departures from complete acetylation of all the amino groups.

Both chitin and chitosan are co-polymers of N-acetylglucosamime and gluosamime. The co-polymer is called chitin when it contains less than 7% nitrogen and chitosan when nitrogen exceeds 7%. Both are found in nature, but chitosan is generally obtained by the deacetylation of chitin. In nature, chitin is covalently bonded to proteins which may also serve to link chitin to carbohydrates. In plants, it serves as an alternative to cellulose and, in animals, as an alternative to collagen. Chitin is insoluble in all normal solvents but can be dissolved in anhydrous formic acid, dichloroacetic acid, trichloroacetic acid, hexafluoroisopropanol, and in a mixture of lithium chloride.

Chitosan, the most prominent chitin derivative in commercial use can be protanated to form a positive centre. This property enables chitosan to attract negatively charged particles to its structure. Chitosan is also soluble in dilute organic acids, dilute hydrochloric acids, hydro-bromic acid and hydro-codic acid.

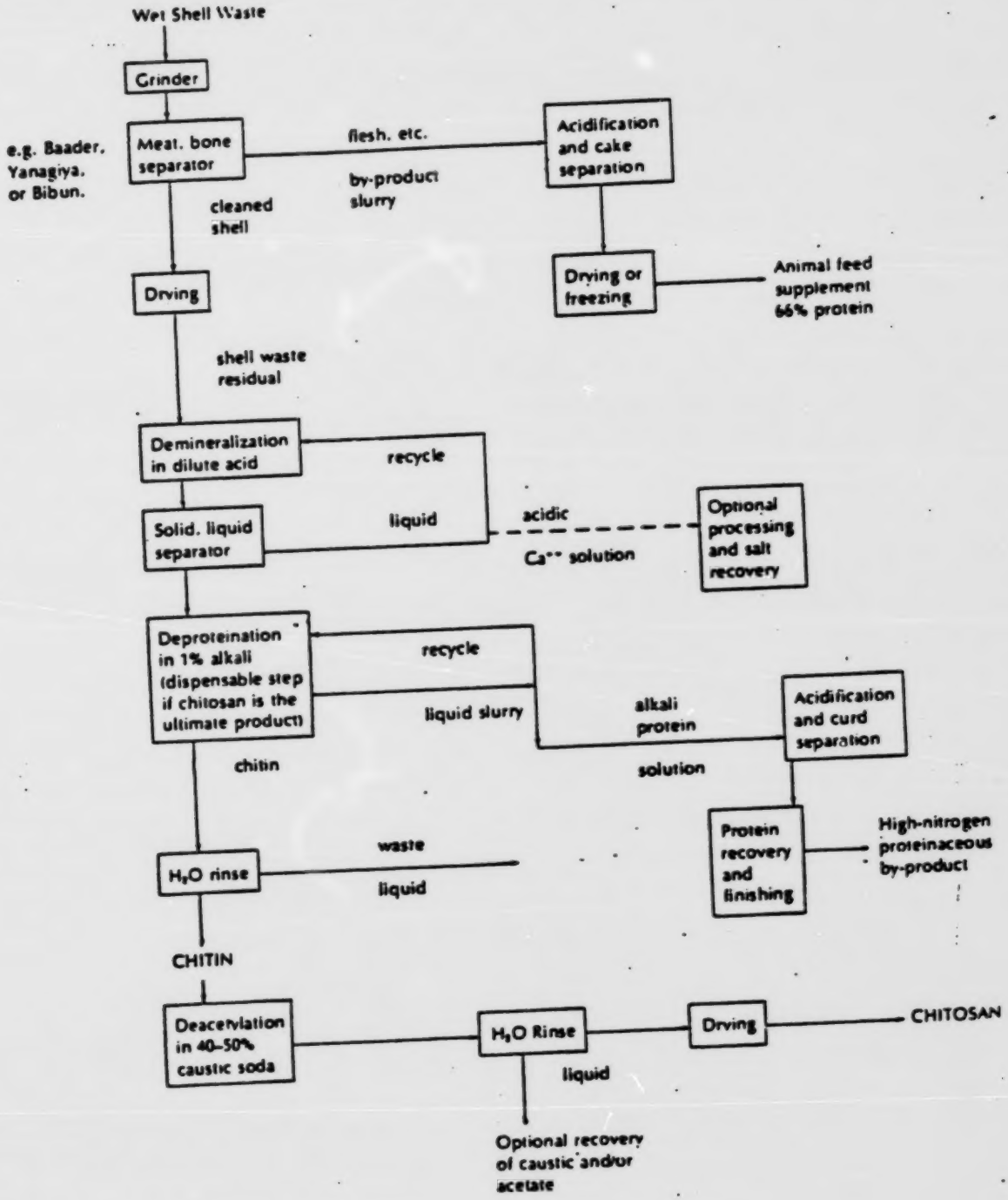
2.1 Production Processes

The production of chitin and chitosan involves a multiple sequence process of harsh chemical treatments applied to shellfish wastes. A generalized model of the process is shown in Exhibit 1. The major commercial source of chitin is crustacean shells. In these shells it is associated with protein and salts which have to be removed to obtain the chitin. Since different species have different concentrations of protein and salt, they should be processed separately in order to obtain the highest grade of chitin possible. Since all processing cannot be done immediately, a large part of the waste must be stabilized by freezing or by washing, grinding and drying as soon as possible. Ground, dry crab meal is stable and can be stored for very long periods. It is therefore essential to have facilities for washing, grinding and drying near every plant processing crustacea. It is also essential that systems be devised in the plant to prevent any contamination of the crustacean shells. Many samples contain pieces of rubber and wood plus other extraneous material.

Protein can be removed by enzymes or by treatment with sodium hydroxide. The latter must be used if the protein and pigments are to be recovered. The protein slurry is acidified with acetic acid to the iso-electric point of the protein, treated with an antioxidant and allowed to coagulate. The material is de-watered by filtering in cloth filter bags or by centrifuging. The protein and the pigments can then be separated by extraction. The shell is then treated with sodium hydroxide to remove additional protein some of which can be recovered as described below. A similar process extracts the pigment from the meal before the protein is removed.

In another method, the meal is boiled in 0.5% sodium hydroxide for about 30 minutes after which the sodium hydroxide solution is removed and the remaining meal is treated in two additional steps with boiling 3% sodium hydroxide. The sodium hydroxide solutions are combined and the pH is adjusted to the iso-electric point

EXHIBIT 1: CHITIN PRODUCTION PROCESS



which causes the protein to precipitate. The pigments remaining in the meal are then bleached or removed by extraction and the meal is treated with hot 1:1 sodium hydroxide to complete de-proteination. The specific process to be used will depend on the species being processed and will largely determine the degree of deacetylation of the product.

Calcium carbonate is removed by treating the meal with hydrochloric acid or with the tetrasodium salt of ethylenediaminetetraacetic acid (EDTA). This treatment largely determines the quality of the chitin, i.e., the amount of mineral remaining and the molecular weight of the polymer. This treatment can either precede or follow the deproteination and will depend on the species being processed.

Chitosan is prepared from chitin by deacetylation with hot concentrated sodium hydroxide. If a high viscosity chitosan is desired, this reaction must be carried out in an inert atmosphere. The treatment times and production conditions will also affect viscosity. Additional treatment is required to produce a very high grade chitosan.

It is also possible to prepare chitosan from chitin by an enzymatic process since, in plants, chitosan is produced from chitin by chitin deacetylase.

2.2 Production Volumes

We estimate that the total world production of chitin and chitosan is in the range of 1,000 to 1,200 tonnes per year. Production capacity is approximately double this amount. Exhibit 2 provides a breakdown by country.

EXHIBIT 2: WORLD CAPACITY AND PRODUCTION OF CHITIN AND CHITOSAN

	Production (Tonnes)	Capacity (Tonnes)	Approximate % of Capacity
Japan	900	1,200	75
United States	50-75	250-275	30
European	30-50	75-100	50
Other	30-50	75-100	50

Source: DPA Estimates

Japan is the world leader in chitin and chitosan production, usage and technology. Extensive research into cost effective production processes and government subsidies on the costs production chemical have allowed Japan to produce chitin at a lower cost than other countries.

Research and development related to chitin in the United States has progressed significantly over the past five years. The extensive research being conducted has given rise to many new applications. However the cost of production and regulatory barriers have mitigated against large scale production in the United States.

There is presently no commercial manufacturing of chitin or chitosan in Canada, however, various companies have shown interest in this area.

2.3 Major Players

The chitin/chitosan industry, although still in its infancy, has attracted attention from a large number of active players.

These players range from academics to large multi-nationals. Industry participants are discussed under the following headings:

- Primary Producers
- Secondary Processors
- Researchers
- New Developments

2.3.1 Primary Producers

These companies produce chitin and chitosan from shellfish or krill waste products. The chitin or chitosan produced is generally sold directly to identified end users or to larger, more specialized companies for secondary processing. The primary producers of chitin and chitosan are:

- Kyowa Oil and Fat, Japan;
- Kattakura Company, Japan;
- Protan Laboratories, United States;
- Kalaallit Tunisassiorfiat, Greenland;
- Marine Fisheries Institute, Poland; and
- Igene Biotechnology, United States.

Kyowa Oil and Fat

Kyowa Oil and Fat, a joint venture of Nippon Suisan Kaisha Ltd. (NSK) and Soda Co., Tokyo, Japan, have pioneered commercial production of chitin and chitosan. NSK has an office in Halifax which will obtain chitin or chitosan from Kyowa if requested. The company's raw material source consists or crab shells (80%) and shrimp (20%). Various contacts have indicated that raw materials are also being imported from Korea, Thailand and Indonesia with more waste being sought.

The company presently produces between 350 - 500 tonnes annually of which 95% is used for waste water treatment and the remaining 5% for research purposes. It is thought that the company is presently operating at 70 - 80% capacity. As previously mentioned, chemicals for the company's production process are government subsidized.

Kattakura Company

Kattakura Company, Tokyo, produces between 350-500 tonnes of chitosan per year for use in waste water treatment. Sources have suggested that the plant capacity is greater than that for Kyowa. The raw material supply is the same as Kyowa and Kattakura is in competition with Kyowa for the same markets for chitin products.

Other Japanese Firms

Smaller companies such as Kyowausi Company, Kyokuyo, Kiwitsui, and Lyon Company produce a maximum of 50-150 tonnes per year in total.

Protan

Protan, a wholly owned subsidiary of Protan A/S of Drammen, Norway, is located in Redmond, Washington. (Protan A/S Drammen also owns a seafood processing company called Protan Scotia Marine located in Shelburne County, Nova Scotia.) Protan, originally called Cypro company and then Marine Commodities Research, was purchased by its present owner in 1984. The company is the only large scale manufacturer of chitin and chitosan in North America.

Protan's raw material source consists of King, Dungeness and Tanner crab shells and Alaska pink shrimp. Other sources include cannery wastes from the Gulf of Mexico and the eastern U.S. coast. All products are obtained free of charge. One contact has suggested that Protan may be having a problem with raw materials supply, although this was not verified by the company itself.

Protan produces between 50 and 74 tonnes of chitin/chitosan per year. Protan's plant is capable of producing 230 MT. Protan has recently expanded their operation by adding fully automated equipment which enables Protan to produce approximately 5000

lb/year of medical grade chitin. The new equipment has been in use since March of this year. The main markets for Protan have been in waste water treatment, with small volumes of sales for research purposes to pharmaceutical, cosmetic, animal feed and food processing applications. Reports suggest that small quantities of chitosan (10-15 tonnes) are being shipped to Protan's parent company in Norway for additional processing which is then sold in Japan and the United States for medical and pharmaceutical research purposes.

Protan has begun to produce chitin and chitosan derivatives targeted at pharmaceutical and cosmetic applications. Their sales of these derivatives are unknown.

Protan has been trying to develop higher grade applications for their chitin and chitosan products. They have applied to the F.D.A. to use chitosan to remove solid particles from fruit juices and other beverages.

Protan has conducted market studies into the use of chitosan as a coating for fruits and vegetables. Another study is to be completed this fall concerning the use of chitosan as a natural fibre in food.

Protan presently offers chitosan in three general grades based on molecular weight and purity (see product specifications in Appendix B). Protan will manufacture chitosan to the custom specifications if desired by customers. Small quantities of ultra-high grade chitosan are being produced on a small scale (by the gram).

Some sources contacted indicated that Protan's general premium grade chitin is actually of low quality. The consistency was described as poor by several respondents. It is claimed that in some cases the product does not meet the claimed specifications on the price list.

Protan's products are shipped directly to end users in plastic bags inserted inside cardboard boxes. The majority of Protan sales are made directly to end users. Recently Kytek, (described in subsequent section) located in Baton Rouge, Louisiana, has begun distributing chitin products for Protan.

Kalaallit Tunisassiorfiat

Kalaallit Tunisassiorfiat, located in Greenland, produces small qualities of chitin from Greenlandic prawn shells. Production volumes and specific market application are unknown. Industry contacts were not aware of the company or the quality of products they produce. This company appears to be producing chitin on a pilot basis. The Company's product spec sheet is contained in Appendix B.

Marine Fisheries Institute

The Marine Fisheries Institute, located in Gynia, Poland is said to be producing chitin and chitosan on a very small scale. (3-5 tonnes/yr). The raw material source currently being used is waste products from the Russian and Antarctic krill fishery. It is believed that the majority of chitosan being produced in Poland is for research purposes targeted specifically at cosmetic and medical applications. The price for this company's chitosan is U.S. $11.00 per pound.

Igene Biotechnology

Located in Maryland, Igene Biotechnology produces 1000-1150 tonnes of "Clandosan" annually. "Clandosan" is the registered tradename of a product combining chitin and protein to be used for the prevention of nematodes in plants.

2.3.2 Secondary Processors

Secondary producers buy chitin or chitosan from existing producers. Additional treatments produce a higher grade chitin

or chitin derivative for particular markets. Existing secondary processors are:

- Bentech Laboratories
- Atomergeric Chemicals

Bentech Laboratories

Bentech Laboratories Inc. (formerly Bioshell Inc.) situated in Clackamas, Oregon, processes high grade chitosan for coating wheat seed with a yield-enhancing agent called "Yea".

Bentech originally purchased raw chitin from Protan. However, recently they have concluded a joint venture with another primary producer. One source indicated that the company is Bioguimica Austral, located in Santiago, Chile. Bentech have not confirmed this. Bentech purchases approximately 12 tonnes of chitosan per year.

Mr. Bentley, president of Bentech, has indicated that raw chitin and chitosan have occasionally been purchased from Japan. It was found that the Japanese were price competitive and extremely competitive on a quality basis.

Bentech has future plans to manufacture a chitin-based topical ointment for wound healing and anti-fungal treatment. Experimental work has been done on the product and Bentech has applied to FDA for regulatory approval. This is probably one to two years away from commercialization, but will eventually open a market for quality chitin.

They have also identified water purification as an important market, but have no specific plans for producing products for this application at present.

Before changing ownership, Bioshell was in competition with Protan as a primary producer. They abandoned the raw chitin market due to the cost of obtaining raw materials and poor

markets. The newly established joint venture has allowed Bentech to obtain chitin and chitosan cheaper than the original Bioshell plant could produce it for.

It is estimated that total sales of "Yea" are close to a million dollars. Bentech is the largest purchaser of chitin and chitosan in North America.

Atomergeric Chemicals

Atomergeric Chemicals, Plainsview, New York obtains raw chitosan from a Japanese supplier (unknown), re-processes it and resells it primarily for research purposes. At present the company is operating on a pilot basis. Reportedly, a carboxy methol chitosan solution is shipped in drums directly to some cosmetic manufacturers who use it for research purposes. Atomergeric Chemicals also offer industrial grades of chitosan in liquid and powder forms. Sales volumes and other market applications are unknown.

2.3.3 Researchers

Research on chitin and chitosan is very active. Research is being conducted into production facilities, production processes, new market applications, and new chitin derivatives. A recent article published on possible food applications referred to 150-200 people conducting research in this area. It is quite possible on an international basis that several thousand people are involved in chitin research in universities and the private sector.

2.3.4 New Developments

Several companies are not directly involved in production but are likely to become involved or are co-venturing with others. The companies are essentially waiting for major breakthroughs in the market while doing research themselves on possible market applications. In North America, these companies include:

- The Chitin Company;
- Hosho Somerset Corp.;
- Farrson Chemicals;
- Kytek;
- Nova Chem;
- Nippon Suisan Kaisha Ltd.;
- Connors Bros. Ltd.;
- United Maritime Fishermen's Association and Griffith Laboratories;
- Canada Packers; and
- Mitsubishi.

There is also considerable activity in other parts of the world.

The Chitin Company

The Chitin Company, located in Cambridge, Mass. operates a small pilot plant. The company is seeking funds for a venture to produce high-quality chitin derivatives. The company holds sixteen patents for specialized production processes and special derivatives, primarily aimed at the biomedical market. The company has also expressed interest in developing chitosan for cosmetic applications as well as for pre-purification of water to be used in food processing.

The company, which also acts in a technical consulting capacity, plans to establish three plants within the next three years.

The Chitin Company is a product of several experienced researchers who have carried out various projects under the Sea Grant Program. Their main areas of interest are Boston, Chesapeake Bay, Florida and the Gulf of Mexico. These locations were chosen because of the abundance of crab shell wastes in each area.

Long term plans for the Chitin Company involve the eventual establishment of a chitin producing facility utilizing carefully

monitored fungi crops. This development is important to watch since, if this technology proves feasible, it may ultimately replace shellfish waste as a source of high grades of chitin. The purity of the chitin and chitosan can be carefully controlled which is particularly important for very high grade applications.

Hosho-Somerset Corporation

Situated in Crisfield, Maryland, Hosho-Somerset utilizes approximately 600 tonnes of wet crab waste per year. Most of the wastes are used in a crab-based fertilizer. The company processes chitin at the pilot plant scale with a full-scale industrial plant supposedly scheduled for construction shortly. The anticipated output of chitin is expected to be 10 tonnes per week.

Their crab shell supply consist of the blue crab species, from fish processors in the Chesapeake Bay area. Experiments have indicated that mineral content is very low providing a high purity level chitosan.

Development work is being conducted on new agricultural applications, specifically as a growth regulator and anti fungicide and pesticide agent.

Farrson Chemical Ltd.

Farrson chemicals, located in Kennewick, Washington is producing a chitin derivative plant growth regulator on a pilot basis. The company has plans to establish a processing facility to produce its own chitosan in 1988.

Kytek

Kytek, located in Baton Rouge, Louisiana, is a distributor for Protan Laboratories. The company plans to utilize Protan's supply until market demand exceeds Protan's capacity. At this

time, Kytek will go into commercial production of chitosan for waste water treatment.

When commercial production commences, the raw materials to be used by Kytek will be crawfish wastes which are available in abundant quantities for 6 - 8 months of the year. Kytek has indicated that this constant supply combined with its proposed specialized production process which will utilize the majority of processing by-products, will allow Kytek to produce chitosan at a low enough cost to make it competitive with synthetic waste water treatment products.

Nova Chem. Ltd.

Nova Chem Ltd., of Halifax, Nova Scotia, produces experimental quantities of a chitosan derivative for coating fruits and vegetables to prolong their shelf life. Its laboratory is located at Acadia University. Regulatory approval has been requested from Health and Welfare Canada for coating apples.

Regulatory approval is expected to take up to two years.

Nova Chem holds a patent on the derivative, which is water soluble and can be washed off the applies before processing or being placed in retail markets. The company plans to establish a small manufacturing plant in the near future to produce this product as well as medical grade chitosan and derivatives.

The strategy adopted by Nova Chem is to purchase low grade chitosan until demand becomes large enough to justify commercial production.

Nippon Suisan Halifax Ltd.

Nippon Suisan Halifax Ltd., is a subsidiary of NSK. The company distributes chitin and chitosan in North America for their parent company in Japan. The quality of chitosan available from this source is reported to be very high.

Connors Bros. Ltd.

Connors Bros. Ltd., located in New Brunswick, have been producing chitin and chitosan experimentally in the laboratory. Plans are underway to develop a 5 tonne pilot plant in New Brunswick in association with NSK. If the quality of chitin and chitosan is suitable, the company will construct a large scale manufacturing facility to supply NSK. However, Connors Bros. have indicated that considerable product development work is required to meet the specifications and production costs necessary for viability.

United Maritime Fishermen's Association and Griffith Laboratories

The United Maritime Fishermen's Association, owned by 2600 fishermen in New Brunswick, is conducting a study into possible market applications for chitin and chitosan, particularly in the agri-food industry. If positive results are obtained, a joint venture with Giffith Laboratories of Toronto may be undertaken to establish a processing facility in New Brunswick.

Griffith Laboratories is a large Canadian company specializing in servicing the food processing industry. This company has recently begun research into the extraction of protein and pigment from crab shells for use as flavorings and colorings in food processing. The company has purchased experimental quantities of chitin from Protan Laboratories.

Canada Packers

Canada Packers of Toronto is examining the possibility of establishing a facility to utilize crab shell wastes. The person contacted at Canada Packers would not reveal any information regarding what actual uses were being considered, but did indicate that they are not interested in chitin or chitosan production.

Mitsubishi

Mitsubishi's office in Montreal has expressed interest in purchasing processed crab meal from Lameque Co-Op. The meal is used in Japan to produce an extract for artificial crab meat as well as for animal feed. Mitsubishi apparently has requested assistance from DRIE to construct a manufacturing facility in Nova Scotia to produce fishmeal from herring roe.

2.5 Activity in Other Parts of the World

Research into chitin/chitosan production is being carried out in other parts of the world. One producer has indicated that he receives samples from different countries almost every other week.

Production of chitosan has been attempted with mixed success in India, Russia, Korea, Brazil, Nicaragua, and Ireland. It is believed that pilot operations do exist in these countries, in anticipation of a major break in the market.

Reports suggest the Chinese are looking at the production of chitin from fungi. If this fermentation process becomes economically feasible it is believed that China would be able to saturate the market with high grade chitin and chitosan. China also supports a very large fishing industry as a potential source of raw materials.

2.6 Market Share by Producers

The listing below provides rough estimates of the approximate market share of the world chitin and chitosan market by producer.

	Market Share (%)
Kyowa	30-40
Kattakura	30-40
Protan	5-10
Kalaalit Tunnisassiorfiat	3-5
Marine Fisheries Institute	< 1
Other Japanese Producers	5-10
Other World Producers	5-10

3.0 CHITIN AND CHITOSAN PRODUCTS

3.1 Properties and Uses

The uses of chitin and chitosan derive from five important properties of the substance:

- high charge density;
- film forming properties;
- coagulation inducement;
- strong binding properties to negatively charged polymers;
- wound healing promotion.

Exhibit 3 shows the examples of some of the uses which relate to these properties.

In the course of our study, we identified perhaps as many as a hundred different applications in various stages of commercialization, research and development.

Chitin and chitosan are not identifiable generic products which have constant properties when processed. Variations due to the production process, the types of acids used in processing, the raw material and additives can all alter the state of the chitin and chitosan. Each use also requires specific chitin/chitosan characteristics. Therefore the basic chitin must be further processed to produce the chitin or chitosan for a particular end use.

There are only three applications which are in current use in any significant volume. Two other applications are in use in countries outside North America. Based on our findings and interviews, we have identified thirteen others that are close to commercialization. At this time, it is impossible to identify which, if any, will actually be market ready over the next five years. However if there are new products, they will most likely come from this group.

EXHIBIT 3: PROPERTIES AND POTENTIAL USES OF CHITIN

	Properties	Uses
1.	High charge density and potential binding capacity	. Ion exchange materials . Chelating solids . Metal recovery . Industrial process water purification . Beverage clarification
2.	Film Forming	. Ion exchange membranes . Coating for seeds, fruits, vegetables
3.	Coagulation	. Waste water treatment
4.	Strong binding to negatively charged polymeric products	. Adhesives . Sausage casings . Paper strength additives . Dye binder for textiles
5.	Wound healing promotion, non-thrombogenic	. Wound treatment . Surgical products

Source: Industrial prospects for Chitin and Protein from Shellfish Wastes: MIT Sea Grant Program, 1977.

In Exhibit 4, we show the products and the expected timing of their commercialization.

EXHIBIT 4: STATUS OF PRODUCT DEVELOPMENT FOR CHITIN & CHITOSAN PRODUCTS IN THE SHORT TO MEDIUM TERM

Current use

- Waste water treatment
- Seed coatings
- Clandosan
- Clarifying agent
- Hair products
- Research

Anticipated Short Term Developments (0-2 years)

- Surgical sutures
- Wound dressing
- Topical treatments
- Fruit and vegetable preservatives
- Fungicide

Medium Term Developments (3-5 years)

- Contact lenses
- Protein recovery
- Animal feed
- Cholesterol reduction agent
- Sustained drug release
- Texture control
- Fibre additive
- Production of amino sugars

The sections which follow describe the products under the following categories:

- Existing uses;
- Short term developments;
- Medium term developments;
- Long term developments.

3.2 Existing Uses

The existing market for chitin/chitosan and its derivative products is concentrated in six main uses:

Water Treatment
Seed Coating
Clandosan
Clarifying Agent
Hair Products
Research

3.2.1 Water Treatment

As stricter regulations are applied to municipal and industrial waste water treatments, more efficient processes and equipment are being used to remove suspended and settled solids, certain metals, and other pollutants.

By simply adding small quantities of chitosan to drinking water supply sources and waste water treatment plants it is possible to flocculate (sludge recovery) and chelate (metal isolation) harmful pollutants. Chitosan's positive charge, a natural characteristic of the compound, makes it very effective for this purpose. The degree to which chitosan is de-acetylated, its combination with other chemicals and the cleaning techniques employed vary with the characteristics of the treatment plant.

Treatment systems may range from mixing chitosan with other solid material such as dietamacious earth to form solid materials for the accumulation of bacteria to simply pouring chitosan into the water stream or large vats. The sold materials either float, and are skimmed off, or accumulate on the bottom of the vat where they can easily be removed.

The main purchase of chitosan for this use is chemical firms specializing in designing processes for waste treatment plants. These companies will specify molecular weight and deacetylation level of the raw chitosan and add other chemicals to make the chitosan most effective for a particular wastewater stream.

Current Status

Chitosan has been used as an agent in waste water treatment and water purification commercially in Japan for the past six to eight years. In North America sales of chitosan for waste water treatment have been negligible. Small volumes of chitosan produced by Protan have been sold for sludge recovery from food processing plants.

Although considerable interest has been shown for this use, its penetration of the market is limited primarily by the price of the product.

Main Users

Specialized chemical companies or branches of large chemical companies specializing in sale of waste water chemicals, systems and consulting services, represent the primary markets. These companies stock a wide variety of waste water products and in many cases, recommend the best flocculation or chelations agent given the particular type of waste water a company produces.

Waste water treatment products and services are used by iron and steel mills, pulp mills, municipal waste treatment facilities, metal manufacturing companies, meat packing plants, wineries and

breweries, chemical companies, electroplating plants, jewelry producers, food processing companies, and water purification operations.

Kurita Water Industries, Japan, is the largest user of chitosan for wastewater treatment in the world. The company has patented one particular use of chitosan for wastewater treatment (details unknown) in Japan, Europe, United States, and Canada. Kurita also distributes a wide variety of synthetic polymers and chemicals in addition to its chitosan products. The primary markets for Kurita are food processing companies, municipal treatment facilities, iron and steel mills and chemical companies.

Kurita purchases its raw chitosan from Kyowa Oil and Fats located in Tokyo, Japan. Kyowa Oil and Fats distributes the specified variety of chitosan directly to Kurita's main storage facility.

Large American companies such as Johns Manville and Hercules have investigated the potential uses of chitosan as a flocculation or chelating agent. Johns Manville, Louisiana, has recently purchased patent rights for a chitosan based process (details not given) to be used in handling of hazardous waste. Johns Manville are now trying to determine if chitosan is effective and economical for chelating hazardous metals found in wastewaters of their plants. This company sources its chitosan from Kytek.

Hercules, a major U.S. chemical distributor, located in Texas, began producing chitosan for waste water treatment in 1973 and again in 1980. In both instances, production was ceased due to lack of sales. Hercules had anticipated high sales for chitosan due to its non-toxic nature. However, the high price of chitosan compared with other synthetic products resulted in very few sales.

Kytek has positioned itself as a specialist in the utilization of chitosan based products for waste water treatment. Their long-

term plans involve producing chitosan to be used in providing a turn key solution to companies requiring wastewater products. Deerborne Chemicals and Cape Cod Research are other waste water treatment companies investigating the potential use of chitosan.

Current Usage

Worldwide, it is estimated that 900 tonnes/year of chitosan are used in wastewater treatment. Ninety-five percent of the chitin is used in Japan. Sales of chitosan for wastewater treatment have increased at a rate of 3-4%/year for the past seven years in Japan. We believe the potential demand for chitosan in Japan is actually much greater but the present high price limits the country's ability to sell more.

In comparison, the volume of chitin used in waste water treatment in North America is very small. Potentially, the market for chitosan as a flocculation or chelating agent could be in the thousands of tonnes annually. However, unless costs of production can be reduced or regulations force more use of the chitosan, the demand will probably grow very slowly, reflecting the growth pattern in Japan.

Competing Products

Chitosan competes with a number of cheaper products on the market such as poly-acrylimides, synthetic polymers and other synthetic fibers such as ferric chloride and alum. These products are available from all large waste water treatment companies at prices ranging from two to five dollars per pound as opposed to chitosan, where the price is four to eight dollars per pound.

Opportunities and Constraints

The use of chitosan for waste water treatment has achieved some market acceptance primarily in Japan. There is already a substantial potential demand in Japan, but chitosan cannot be manufactured at a price competitive with other products. It is

evident from the steady demand in Japan that the potential for considerably more usage does exist. The conditions in Japan are quite different from North America:

- Extensive research and development is continually being conducted in Japan into more cost-effective means of production;

- The Japanese government subsidizes the expensive chemicals used in the production process;

- Because disposal of shellfish wastes is expensive and an environmental problem, the Japanese government imposed regulations requiring the use of chitosan in water purification to encourage using more of wastes.

- The lack of waste water disposal sites in Japan has forced many companies to set up incineration operations. By using chitosan, these companies can reduce the moisture content of the waste by 30% as opposed to 10% by using artificial polymers. This results in lower fuel costs during the incineration process.

The main constraint to the use of chitosan in waste water treatment in North America is cost. Economies of scale and cheaper processing methods should increase chitosan use in North America. Also, changes to regulations requiring more use of non-toxic agents will make its use more widespread.

3.2.2 Seed Coating

Chitosan covers wheat and pea seeds with an adhering glossy coat. Depending on weather conditions, treatment with chitosan increases yields from 10 - 30 percent.

Chitosan possesses three chemical properties which affect plants:

- making attacking fungus less pathogenic;
- inducing a disease-resisting response in plants; and
- acting as a growth stimulant.

Chitosan treatment also provides protection against lodging (stem bending and breaking). This provides a higher-yield crop since more wheat heads are recovered when harvesting.

The seed coating, now commercially available in a liquid form from Bentech Laboratories is sprayed directly on the seeds before planting. Approximately 16 oz. of "Yea" (the brand name for the product - Yield Enhancement Agent) is required for 100 pounds of seed. An acre requires 50 - 60 pounds of seed, and "Yea" coating costs about $1.20 per acre.

Current Status

The use of chitosan as a seed coating has received regulatory approval from the U.S. Environmental Protection Agency for twenty states. Mr. Chris Bentley, President of Bentech, explained that approval from EPA only took 10 months as compared to the standard seven to eight years of regulatory red tape.

Main Users

Bentech Laboratories is the only commercial producer of a chitosan-based yield enhancing agent.

The raw chitosan is purchased directly from Bentech's supplier in flakes or granular form.

The end users for this product are individual wheat growers, Agricultural chemical dealers, Seed Companies and seed coating companies.

Usage

Bentech sales of "Yea" for 1986 were between $500 - $800,000. Bentech believes this figure could be as high as $10 million by 1990. We estimate that current use represents approximately 8-10 tonnes of chitosan.

The total potential market for chitosan for this use in North America could be as high as 100 tonnes annually for wheat seed coating alone if Bentech is able to expand sales at its anticipated rate. The potential also exists for its use on oats, barley, peas, beans and rice.

Competing Products

At present there is no direct substitute for this product. Various fungicides and soluble fertilizers represent indirect competition. The chitosan coating differs from normal fungicides. Rather than actually preventing fungal infection, chitosan associates on the cell of the plants DNA molecule and produces a positive change. This increases the plant's immunity to infections.

Opportunities and Constraints

While the market potential for chitosan in seed coating appears optimistic, there are constraints to be overcome before large scale penetration is achieved. These include:

- End user awareness. It will be necessary to educate fertilizer and chemical dealers about the benefits of "Yea". Normally, seed handlers, who clean and apply fungicide treatment to wheat, follow farmers' specifications. Farmers turn to fertilizer and chemical dealers for advice on materials and applications.

- Additional mixing equipment. Seed coating requires a separate process as the chemical composition of chitosan will not allow it to mix with existing treatment agents;

- Seed companies are primarily interested in selling seed, not different seed treatments;

- Additional farm-based equipment. Between $2,000 and $3,000 is needed for the pump and accessories to apply "Yea".

Notwithstanding the above, good market potential exists for this product, specifically in areas where there are known disease problems.

3.2.3 Clandosan

General Description

Clandosan, the brand name of a protein and chitin solution, is reportedly an effective nematodicide. The product's properties stimulate the growth of soil micro-organisms which in turn act as an effective agent against nematodes. Clandosan is available in granular form. The suggested application rate is 1-5 tonnes per acre, depending upon the crop, type of field, and nematode concentration. The product is general tilled into the ground before planting. Clandosan retails at approximately $800 per tonne.

Current Status

Chitin in Clandosan form has been sold commercially for the past two years.

Producers

The only producer is Igene Biotechnology of Maryland. This company processes crab shell wastes from nearby canneries to produce Clandosan. It is our understanding that the production process eliminates all unseen particles other than chitin and protein from crab wastes. The actual product is a combination of materials rather than one built up from chitin. This is not technically a chitin product, however, this application is important as the product competes for large volumes of crab shells.

Research is being undertaken to provide Clandosan in liquid form.

Clandosan is sold primarily to commercial farming operations in the south eastern United States specializing in high value cash crops.

Demand

At present, the demand for Clandosan is 1000-1300 tonnes annually. It is anticipated that this volume could increase by a factor of 20 over the next five years.

Barriers

The primary barrier for Clandosan has been the lack of product awareness. Reportedly Clandosan is substantially cheaper than similar toxic chemicals such as Temik or ethylene bromide, however the general lack of knowledge about the product or what is does has been identified as the major hurdle to increase sales.

3.2.4 Clarification Agent

General Description

Chitosan in 1% active acid can be used to purify beverages from materials, yeasts, and micro fungi from various suspensions. Chitosan used for this application must have a high purity level as small quantities of chitosan will remain in the liquid.

Current Status

Chitosan is used by breweries, wineries and fruit juice companies in Europe.

Approval has not been granted for this use in North America, as health officials are concerned about the quantities of chitosan that will remain in the liquid.

Producers

The main producer of chitosan for this application is believed to be Protan A/S Dammerran located in Norway. Sources have indicated that the company purchases raw chitin and chitosan from Protan Laboratories in the U.S. and reprocesses it.

Demand

The total amount of chitosan used in beverage clarification is less than 10 tonnes/year.

Barriers and Opportunities

The main hurdles have been regulatory approval due to the unknown effects of chitin on human metabolism and price.

3.2.5 Hair Products

General Description

Chitosan, when incorporated into shampoos and hair conditions preparations, imparts improved body and set-holding capacity to hair. It also improves gloss and easier dry and wet combing. Chitosan's positive charge helps hair-care products form a film in contact with negatively charged hair molecules. Applications have been developed in hair setting lotions, mousse and shampoos.

The shampoo derivative consists of low molecular weight amino polysaccharides derived from chitosan and hydrolysed keratin. A high purity level is required.

Current Status

Chitosan is currently approved for commercial use in shampoos in Europe. Regulatory approval in North America will probably come before the end of the decade.

Main Users

Wella Company, of Darnstadt, West Germany has the patent for this derivative in several countries. Wella has used chitosan in its hair products for six years. Experiments were conducted by Wella's sister company in the United States in the early 1980's. At that time the company encountered difficulty in trying to develop chitosan with suitable characteristics. Since then research has only been conducted in Germany. We have learned that Wella is conducting experiments on chitosan use in facial creams, hand lotions and emulsifiers. It is reported that Clairol Corporation and Amercol, a division of Union Carbide, have been conducting extensive research in this area, but we have been unable to confirm this.

Wella Company buys chitosan from a company in Japan (name unknown). The company has indicated that it is satisfied with

the quality and consistency of materials received. He explained that various chitosan suppliers were tried before deciding on this supplier. Raw chitosan is obtained in granular form at a price in the range of $15-$20 per kilogram.

Demand

The total demand for chitosan for shampoo is about 5 tonnes. This is the annual chitin use by Wella. We believe that other cosmetic companies are experimenting with chitosan on a much smaller basis. Chitosan purchased in the United States for cosmetic firms have only been for experimental purposes (50-100 lbs per company).

Because of its non-toxic nature, this product will likely enjoy much more use in the future. The negative publicity received by hair care companies using harmful chemical additives may force the whole industry to turn to natural materials.

Competing Products

Various forms of synthetic resins are available at a lower cost to the company. However, as previously indicated, the non-toxic nature of this product makes the price difference a less important barrier.

Opportunities and Constraints

The primary barrier to more commercial use in North American is regulatory approval and price. Regulatory approval could probably be achieved within one to two years. However, unless legislation is passed requiring fewer toxic materials in shampoo, the price will probably remain a major barrier. It is the main reason sales are not higher in Europe.

3.2.6 Research Facilities

Researchers represent a final category of chitin and chitosan users. However, quantities are very small or negligible in individual cases, never greater than hundreds of pounds per year and probably less than a hundred in most cases.

The amount of chitin/chitosan used in research will grow over the next few years. Increased regulatory approvals, increased industry awareness and intensified research activity should result in more large commercial companies conducting experiments into chitin/chitosan use.

3.3 Anticipated Short Term Developments

3.3.1 Surgical Sutures

By cold-drying chitin, the molecules can be ordered to produce a slender and unbreakable filament which can be used for surgical sutures. Chitin sutures are absorbable, a trait common to only a few suture materials. The suture is non-allergenic, producing essentially no tissue reaction compared to other products on the market. Because chitin sutures are bio-degradable and have wound healing properties it makes this product an attractive option to conventional alternatives. Regulatory approval has been granted for the sale of surgical sutures in Europe and Japan, however, FDA approval has not been granted in North America.

Sutures require a very pure chitosan. It is extremely important that mineral and protein content is kept at a minimum. Purified, slightly modified chitin powder is dissolved in an amino-LiCl solvent to make the dope from which the filaments are spun.

Main Users

Unitika Ltd., of Ugi, Japan, has exclusive world wide rights for chitin-based sutures under license from the University of

Delaware. Most development work on sutures is being conducted in Japan.

The Japanese Pink crab, (Japanese supplier is unknown), is the source of the chitin used by Unitika.

Demand

Demand in North America could potentially be in the 50-100 tonne range, assuming all suture material now in use could be converted to chitin-based material.

Competition

Although there are other absorbable sutures available, their use is limited by the biomedical conditions of application, such as acid, alkali, or the enzymatic environment. Chitin-based products are believed to function more effectively under these conditions and chitin's natural wound healing abilities will be a major attribute.

Barriers and Opportunities

The primary barriers for this application in the U.S. are regulatory approval and strong competition from competing products. It is believed that regulatory approval will be achieved within the next couple of years.

3.3.2 Wound Dressing

Chitin has had remarkable success in experimental trails for healing wounds and burn treatment. A chitin-based bio-degradable dressing for ulcers, burns and other abrasions is expected to be approved for tests on humans within six months. The transparent dressing is applied to the wound area without adhesives and after one or two days will seal itself. Applying the chitosan dressing to the wound area increases healing as well as provides a

soothing effect. The chitin-based dressing has several advantages over conventional products.

- it adheres to underlying tissue and is elastic;
- it is permeable to oxygen and acts as a bacterial barrier;
- it does not require stripping in later stages of wound healing. It hardens into a protective scab and falls off naturally.

Chitosan used for dressings must be 90% deacytated. A high molecular weight, purity level and viscosity are also required. The origin and age of the crab shell used is also believed to make a difference in the quality of chitin required for this use.

Main User

Two large medical supply firms are doing most of the product development. Kendall, a dressing and bandage manufacturer and a subsidiary of Colgate-Palmolive has exclusive international rights to license its dressing composed of keratin, collagen and chitosan. Kendall is now making chitosan dressings on a pilot level in Boston.

Kendall has conducted tests on the quality of chitosan purchased from both Japanese and American suppliers (specific names were not available). Mr. Richard Johanson, director of business development at Kendall, indicates that their main concern is quality as opposed to price. Mr. Johanson indicated that they would gladly pay a premium for a consistent high purity and deacetated for of chitosan. They presently buy chitosan being in flakes at a price of $15 per pound for 20 pounds.

Unitika have developed a dressing consisting of numerous chitin fibers spun or matted together. Unitika markets this project as a protective coating for burn victims. This artificial skin, developed at the University of Illinois, is now undergoing clinical trials in the United States. A Japanese company, Fugi

Spinning Company, has also been reported to be conducting experiments on chitin in wound dressing.

Estimated Demand

Anticipated sales for these dressings could be in the tens to hundreds of millions of dollars. The price for a 4" X 4" dressing could range from $2 - $20.00. The total U.S. market for surgical dressings is approximately 150 million dollars.

The market is potentially very lucrative for a chitosan supplier. This is not a high volume market (the whole world demadn for dressings could be met with 50-100 tonens of chitosan), but the unit selling price is very high, reflecting the ultra-high grade chitosan required in the dressings.

Competing Products

A similar dressing called Duro-derm is marketed by E.R. Squibb. This product retails at $3.75 U.S. (4" X 4" dressing). The chitin product should be a superior product due to its wound healing properties.

Barriers

Regulatory approval for these dressings in the U.S. is two to four years away. They are already approved for use in Japan.

Another barrier to be overcome is the production process. Difficulties have been experienced in trying to produce a consistent quality of dressing, owing to lack of consistency in the chitosan supplied to the dressing manufacturers.

3.3.3 Topical Treatments

The application of a chitin derivative powder or solutions on certain types of infections, abrasions and cuts appears to permanently clear up the infected or wounded area leaving no scar tissue. Experiments have revealed that the application of chitosan-based ointments has accelerated healing of wounds by up to 50%. Applied as a topical ointment or powder chitin, has the ability to keep the wound site clean.

The use of chitosan as a topical treatment for infection is still at experimental stages both in North America and other parts of the world.

Main Users

Bentech Laboratories, Oregon has applied for FDA approval to test their wound healing and anti-fungal ointment.

Unitika is also believed to be conducting assessments on chitosan based ointments.

Demand

Bentech plans to market their products to large pharmaceutical companies on an international basis. Mr. Bentley, President of Bentech, estimates the sales for this product could be as high as ten million dollars.

The total future demand for chitosan for this application could be in the 50-100 tonne range. However, a market ready product and significant market penetration is probably 2-3 years away.

As in other applications, the ointments will have to follow lengthy clinical trials and regulatory approvals. Also, the ointment market is very competitive and covered by major pharmaceutical manufacturers. They will have to be convinced of the superiority of chitin-based products. However, if chitosan-

based topical treatments can prevent scar tissue, it is expected that the product could enjoy substantial market penetration.

3.3.4 Fruit and Vegetable Preservatives

Nova Chem has developed a preservative for fruit and vegetables using a chitin based derivative (N.O. carboxy methol chitosan) with the brand name "Nutri-Save". Nova Chem has also patented a process to produce the coating material. When fruit is dipped in the solution, a permeable membrane forms around the fruit preventing oxygen penetration while allowing ethylene to escape and retarding the decay of the fruit. The coating is colorless, tasteless and edible. It is possible, under the right conditions, to store apples for up to 12 months.

This application requires a high quality chitosan derivative with a high purity level. The company's request for commercial approval was submitted to Health and Welfare Canada in 1983. It is anticipated that the approval to develop a pilot-scale plant will be obtained in the next one to two years.

Main Users

Nova Chem Ltd. have developed the technology. The company purchased a thousand pounds of chitosan derivative from Japan five years ago in flake form at a price of $15 to $20 per pound.

The intended market for the coating is fruit and vegetable producers and packing houses in Canada and the United States who sell to commercial processors. The potential exists to sell to the fresh retail market also. However, it is believed that regulatory approval will be granted sooner for commercial processing. Apple processors wash the fruit before processing, whereas regulatory agencies are concerned about chitin being left on the fruit if sold unwashed through retail outlets.

Estimated Demand

A study conducted by the Nova Scotia Research Foundation in 1983 estimated Canadian demand for Nutri-Save for apple coating to be in the order of 10 tonnes annually. This estimate was based primarily on coating apples for retail sale. Since that time however, Nova Chem has focused on coating apples used in processing to accelerate regulatory approvals. Coating retail apples still represents a viable market option, but regulatory approval will be slower.

It is estimated that the total demand for apple coating in North America could ultimately be as high as 600 tonnes annually. Within two years, it is unlikely that Nova Chem will require more than 8-10 tonnes. This will increase as the company is able to penetrate other North American markets and markets elsewhere. Also, as the application receives market and regulatory acceptance for apples, other products are likely to be treated as well.

Opportunities and Constraints

The use of this chitosan for fruit and vegetable preservation holds very good long range potential. The Nova Scotia Research Foundation received very favorable responses from all persons contacted during the study. Nova Chem indicate that the potential for other fruit and vegetable applications appears optimistic both in Canada and the U.S. Regulatory approvals appear to be the only market barrier.

3.3.5 Fungicide

Research is being conducted on the use of a chitosan derivative as a plant growth regulator and fungicide. This is being undertaken by Farrson Chemicals, located in Kennewick, Washington. Farrson's management would not provide information pertaining to the product's composition or application methods. Once developed, this product would compete for some of the same

market as Bentech's seed coatings. Farrson Chemicals has applied for patent rights for their application.

It is expected to be two years before this product will be available commercially. At present, research plots have been established in various parts of the world to test the product's effectiveness.

Like Bentech, Farrson Chemicals will sell to wheat and rice growers on a national, and possibly international basis. Sales are anticipated to be in the millions of dollars. Mr. Donald Freepons, head of research development for this project, has indicated that product development is currently at a stage where they are no longer are concerned whether the product will increase crop performance, it is just a matter of determining the product composition required to maximize crop yield. Farrson's believes this product will be far superior to Bentech's "Yea" in the benefits it will provide.

Demand

(see "Seed Coatings")

3.4 Medium Term

3.4.1 Contact Lenses

When chitosan is added to the material in contact lenses it makes the lens highly permeable to oxygen, thus allowing the wearer to keep the lenses on for longer periods of time. Therapeutic contact lenses to protect injured eyes while they heal are also being developed.

Another advantage is in the lens production process. Chitin allows the lenses to be molded as opposed to being put through the normal machine processes. Contact lenses of this type may be made very cheaply in both hard and soft variety.

Current Status

This application is still in exploratory stages. Regulatory approval for this application is expected within the next three to five years.

Main Users

Most development work on chitosan's use in contact lenses has been conducted by Professor Graeme Allan at the University of Washington.

Revlon's Barnes Hind are presently conducting laboratory experiments on these lenses. Persons contacted at Barnes Hind have indicated that initial research has yielded positive results. Only research quantities of chitosan have been purchased from Protan Laboratories and other Japanese firms (unknown).

Research is also being conducted by an American optical firm called Frigitronics.

Demand

The quantity of chitosan now used is very small with only research quantities of 50 lbs/year being purchased by larger companies. The total potential demand for chitosan is not expected to be large. If every contact lens in North America was made from chitin, demand would be approximately 20 - 30 tonnes.

3.4.2 Protein Recovery

Chitosan may be used to recover protein from the waste water of fruit and vegetable processing plants. Food processors can save edible wastes that would normally go down the drain. This application provides a means for food processing companies to reduce waste disposal costs by selling the recovered protein for animal feed.

Current Status

Regulatory approval has been granted by American Feed Control Officers (AFCO) to experiment with the use of chitosan-recovered protein.

The use of chitosan for protein recovery is still in experimental stages with no commercial sales reported to date.

IPEC Consultants, located in Vancouver, have reportedly purchased one to three tonnes of chitosan from Protan which they have sold in experimental quantities to a number of slaughter houses. IPEC specializes in selling water treatment equipment and solutions.

Demand

There is presently no demand except for experimental quantities. However, the potential demand could be in the thousands of tonnes annually if food processing companies were to adopt this method of protein recovery.

Barriers

The market barriers are prices and regulatory approvals.

Food processing companies will have to be convinced that the cost of chitosan and the additional costs in storing, shipping and marketing the recovered protein will offset disposal costs.

If food processors are eventually required to treat wastes in this way, the market will open substantially. However, only very low levels of chitosan are permitted (not to exceed 1 Mg/lt).

The potential is very large, easily in the thousands of tonnes if the costs can be reduced and regulatory approval obtained.

3.4.3 Animal Feed

Small amounts of chitin added to the diets of chicken and calves make the animals capable of digesting lactose, the sugar found in milk by-products which animals and humans find indigestible. The utilization of 2% chitin in whey has been used experimentally as an additive constituting 20% of the normal feed diet.

Experiments conducted on rats have proven that adding small quantities of chitin to their diet increases the nutritional value of the food, thus resulting in increased growth (10-15% increase in a one month period has been demonstrated).

Current Status

Regulatory approval has been granted by the U.S. Department of Agriculture permitting 0.1% of chitin in the total animal feed diet. However, chitosan use as an animal feed additive is still in the experimental stages.

Main Users

Large commercial farming operations and feed companies represent the major end users for chitin's use as a substitute to animal feed.

John Zikakis, Dept. of Animal Science at the University of Delaware is currently North America's leader in research into chitin use as an additive to animal feed.

Mr. Zikakis has stated that twelve animal feed experiments utilizing chitin have been conducted in Japan and North America.

Demand

Only experimental quantities are being purchased at present. However, the potential demand for chitin in animal feed could be in the thousands of tonnes.

Barriers

The identified constraints prohibiting chitin use in animal feed are:

- More research is needed to convince regulatory bodies and farm operators that the chitin fed to animals will not affect the meat being sold for human consumption
- Efficient methods for preserving, transporting and packaging whey will have to be developed
- The quantity of chitin approved for use is too low to provide the real potential benefits to the animals
- Feed companies and large commercial farming operation have to be convinced to alter present feed handling operations. (It will have to be proven that a real cost savings will be incurred by the end user.)

3.4.4 Cholesterol Reduction Agent

Studies have proven that pure chitosan, when taken internally, has the ability to reduce cholesterol levels in humans. Proponents of this use of chitosan suggest that a small daily dose should be taken in tablet form or as a powder additive to various foods.

Current Status

Extensive research has been conducted on chitosan's effect on animals, however, regulatory approval has not been granted for human experiments. (Regulatory approval for human experimentation has been applied for and is expected to be granted within the next year.)

Main Users

Interest has been shown by several pharmaceutical and food companies. Mr. Ivan Funda of General Mills, Minneapolis, presently holds the patent on this application. General Mills

uses raw chitosan in its laboratory at a rate of 100-150 lbs/ year.

Demand

There is presently no demand for chitosan as a cholesterol reduction agent. The total potential demand could be in the thousands of tonnes per year in North America if chitosan proves superior to other products on the market.

Competing Products

Competing drugs are Cholestyramine and Colstipol. Proponents state that the chitosan drug will be cheaper, safer and at least as effective as these existing drugs.

Barriers

Long term, the potential for this application looks very promising. Clinical trials are still needed to prove its efficacy. This is expected to take five to ten years.

Developing the high grade chitosan for this use will require extensive research and expensive processing techniques.

3.4.5 Texture Control

Chitosan can be used to alter or control the functional properties of foods as a thickener, to control foam, improve cling, improve moisture uptake, work as a gelling agent and control ice crystals.

Current Status

Chitosan's use in texture control is experimental with any widespread use is not expected for at least five years.

Main Users

Dr. Dietrich Knorr of the University of Delaware is the primary researcher in this area. Research quantities of basic chitosan are brought from Protan Laboratories at a price of $7.00/lb. Dr. Knorr has developed several texture products on a laboratory scale at the University.

Griffith Laboratories, Toronto and Weston Corporation, Montreal, is also been conducting research into chitosan use for texture control.

Demand

The demand for chitosan in providing texture control in foods is presently non-existent. If chitosan attains widespread use eventually, the volumes of chitosan used would be in the hundreds of tonnes annually.

3.4.6 Fibre Additive

Chitosan can be added to cereals or breads to provide a good source of roughage for the human diet. The enzymes in the human stomach are unable to breakdown chitosan making it an excellent fibre additive.

Current Status

Chitosan's use as a fibre additive is still in experimental stages. No widespread use is anticipated for another seven to ten years.

Main Users

Dr. Dietrick Knorr, Food Science Department, University of Delaware, is the leading researcher in this field.

Several food producing companies are conducting related research. FMC Corporation, New Jersey, appears to be the most active.

Demand

The potential demand for chitosan as a fibre additive is probably in the hundreds of tonnes. Purity level of the chitosan is extremely important.

3.4.7 Sustained Drug Release

The release of drugs into the human body can be regulated by adding a chitosan solution to the drugs. When combined with chitosan these drugs cause body enzymes to degrade the drug at a much slower rate. This application is particularly important in treating cancer tumors and providing insulin to diabetics.

Current Status

This application is still in experimental stages. Extensive use is 5-10 years away. Clinical trials have not been applied for.

Main Users

The main users will be large pharmaceutical companies. Work is currently being undertaken by FMC Corporation, New Jersey.

Demand

Demand is impossible to forecast with any precision. It could be hundreds of tonnes.

3.4.8 Production of Amino Sugars

Chitin can be used to produce amino sugars through a process which beaks down into sub-units and glycosimine is extracted from the chitin polymer. The glycosimine is then used in the production of amino sugars.

Main Users

The Chitin Company is presently conducting research into this market application.

Potential Demand

Unknown

3.5 Long Term Development

There are numerous other products being developed or experimented with. Most are in the experimental stage only and do not represent an immediate opportunity. These include:

- Paper Additives
- Aquaculture feeds
- Bonding material (adhesives)
- Photographic film
- Lubricants for contraceptives and surgical gloves
- Ionic bonds and films
- Casting of coatings, resistant to water transpiration
- Baby food additives
- stomach anti-acid additives
- Textile finishing
- Water based paints emulsion
- Glass fibre modification
- Specialty adhesives

- Membranes for food wrapping
- Dye in glass fabrics
- Soil repellent on clothing
- Shrink proofing of wool
- Leather tanning

All of these applications are many years from commercialization. The few, such as tanning and shrink proofing, which have no implications for human consumption, may be in production sooner (if there are markets). However, those involving consumption or medico-pharmaceutical uses will still be facing the longer term problem of proving that chitin has no deleterious effects on human health.

4.0 THE MARKET

4.1 General Overview

The chitin and chitosan market can be described as one which is in a state of development. It has been in this state since the late sixties and few market opportunities actually exist. All of the plants in the world operate well below capacity. However, the market appears ready for some major breakthroughs in the next two years, particularly in the medical field where chitin has some very beneficial and unique healing properties. The intensified research from academics and the on-site experiments being conducted by a large number of companies point favorably to increased product usage as do the large number of patents registered for chitin and chitosan uses and production processes. As a result of this activity, several players are positioning themselves to be able to take advantage of the market opportunities as they break.

The three major factors hindering more widespread international market acceptance of chitin and chitosan are the high cost of production, difficulties in maintaining standards of quality and government regulations. The high cost of production and quality problems will probably be solved as the market expands and firms can take advantage of economies of scale. On the other hand, substantial market development is needed before a large operation can profitably survive. This fact is evident by the large number of producing companies who have who have come and gone over the past number of years.

For the higher quality, high mark-up applications involving human consumption and medico-pharmaceutical uses, the major market barrier is regulatory approval. Because relatively little information is known about chitin characteristics on human metabolism, government officials have been reluctant to grant regulatory approval.

The chitin market is an international market. Throughout the course of the study numerous companies were identified as looking into chitin/chitosan usage possibilities in countries all over the world. However, at present Japan is the only country which markets and uses chitin and chitosan in any significant volume.

An issue in developing market estimates is the difficulty in obtaining reliable information. Established producers are very reluctant to provide information on their existing uses or even the types of applications themselves. This is obviously a sensitive area given the very limited market opportunities now available. Researchers and producers are generally reluctant to share information which they feel may result in their ideas being taken by others.

4.2 Channels of Distribution

Chitin and chitosan are distributed directly to end users by producing companies. Almost all researchers purchase directly from producers. Research quantities are also available from large chemical distributors who have small quantities on hand or have access to a larger supply. A list of chemical distributors identified as suppliers of chitin and chitosan is included in Appendix C.

Companies involved in chitin and chitosan production presently lack an adequate sales force. Because volumes are small and the market widespread, most sales activity is by word of mouth and circulation of price lists and brochures. Although company brochures are available, anyone wishing to purchase chitosan has to do a considerable amount of digging to find information.

4.3 Market Segments

Although, as the previous section has shown, every application is different and producers produce their chitin and chitosan for specific applications, it is helpful to consider the potential market as comprising three broad market segments. These segments

are related to product quality requirements. producers tend to produce different grades of chitin to meet the needs of each segment. Grouping by grade of the product helps to conceptualize the options for a producer and the strategies followed by the present players.

We have arbitrarily labelled these segments as:

- Low grade segment;
- High grade segment;
- Ultra-high grade segment.

4.3.1 Low Grade Segment

The major uses of low grade chitosan are:

- waste water treatment;
- Clandosan;
- protein recovery from food wastes; and
- animal feed.

Low grade chitin/chitosan products are the cheapest to produce and the most common. In all of these applications raw chitin or chitosan is used more or less in the form purchased from processors. These products are used for applications where the content of protein and salt is relatively unimportant. The production process does not have to be technically advanced. Although the purity level should be kept as high as possible it is not a major determinant.

In the production of basic chitin and chitosan, pigment and protein are desirable by-products and should be recovered if possible. In obtaining these by-products less attention tends to be focussed on the characteristics of the chitin/chitosan product. In contrast, for higher application it is better to concentrate on the quality of the chitin/chitosan and only recover protein and pigments if the recovery does not reduce the quality of the product.

4.3.2 High Grade Segment

Applications using high grade chitin/chitosan include:

- Shampoos;
- Seed coatings;
- Fungicide;
- Fruit & vegetable preservation; and
- Clarifying agent.

High grade applications require fairly pure chitin to start with. Other materials are added or the chitin is subjected to further processing. To produce a high grade chitin/chitosan and product requires processing of raw chitin or chitosan adapted to a specific application. The quality of chitin and chitosan needed for high grade application is presently not commercially available in North America.

4.3.3 Ultra/High Grade Segment

Ultra/High grade applications are those which require the highest purity chitin and chitosan. They are generally (though not always) characterized also by high molecular weight. Because of the extensive research testing requirements and technical capabilities required to produce consistently pure chitin and chitosan and the costly chemicals involved, high quality chitin is expensive. The highest grade products are used in medical and pharmaceutical applications where a highly pure, calcium-free chitin is needed.

Examples of ultra/high grade chitin/chitosan applications Include:

- Texture Control
- Fibre Additives
- Surgical Sutures
- Wound Dressing
- Topical Treatments
- Contact Lenses
- Sustained Drug Release

- Cholesterol Agent
- Production of Amino Sugars

The production of ultra/high grade chitin/chitosan products is usually done by academics and researchers who purchase raw chitin of the highest possible quality available and then treat the substance to produce the desired end product.

4.4 Product Characteristics

The three main characteristics of chitin and chitosan which are most commonly specified for each application are purity, molecular weight and deacetylation level. Purchasers' specifications may be very precise, particularly in the case of ultra-high grade applications, or they may be very general when the application does not require a high quality of product. Generally, even chitin suppliers are not precise about the specifications of their products. Some may simply supply one grade and give the chemical analysis (see price sheet for Kalaallit Tunisassiorfiat in Appendix B, for example). Other suppliers such as Protan, sell different grades, meeting different levels of quality.

Purity reflects the level of contaminants in the chitin. These impurities include ash, protein, metals, colour, etc.

Molecular Weight. Molecular weight of chitin is important because many products require molecular weights within a very narrow range. Some products only require a maximum or minimum, molecular weight. There is also a group of products for which molecular weight is not important.

Deacetylation Level. Deacetylation of chitin breaks down the chemical chain into smaller molecules each with a positively charged particle. The higher the level of deacetylation, the greater the positive charge in the molecules of chitin which remain. The positively charge product is important in uses involving chitosan as a chelating or flocculating agent.

For some applications, other properties are also important.

- viscosity (directly related to molecular weight);
- percent amine on the degree of deacetylation;
- solubility rate;
- moisture content;
- bulk density;
- NH2 content; and
- ash content.

Exhibit 5 gives a summary of the characteristics of chitin and chitosan used in the various applications referred to in this section. The classification system, developed in discussion with Kytek, is somewhat arbitrary but gives a general indication of the nature of the materials required by end users. It is important to understand that each market application requires a specific type of chitin or chitosan which are influenced by factors such as the raw material source, the particular of species, the process used, the type of chemicals used and even testing standard. Chitin and chitosan cannot be produced as a generic commodity product for immediate end use in all or even a few market applications.

EXHIBIT 5: CHARACTERISTICS OF CHITIN AND CHITOSAN REQUIRED FOR VARIOUS APPLICATIONS

Application	Form	Molecular Weight(1)	Purity(2)	Deacytelation Level(3)
Ultra/High Grade				
Texture Control	chitosan	unknown	high	unknown
Fibre Additive	chitosan	unknown	high	unknown
Surgical Sutures	chitin	high	high	N/A
Wound dressing	chitin	high	high	N/A
Topical treatment for infections	chitosan	high	high	high
Contact lenses	chitosan	high	high	high
Sustained drug release	chitosan	high	high	high
Cholesterol reduction	chitosan	high	high	high
Production of Amino Sugars	chitin	high	high	unknown
Low/High Grade				
Hair care products	chitosan	low	medium	high
Seed Coating	chitosan	low	medium	unknown
Fungicide	chitosan	low	medium	unknown
Fruit and Vegetable preservative	chitosan	high	medium	immaterial
Clarifying Agent	chitosan	immaterial	medium	high
Low Grades				
Waste water treatment	chitosan	low	low	high
Protein Recovery	chitosan	high	low	high
Animal Feed	chitin	immaterial	low	N/A
Clandosan	chitin	immaterial	low	N/A

(1) Molecular Weight:
(measured by viscosity)
Low - <350 centipose
Medium - 350-800 centipose
High - 800-2500 centipose

(2) Purity:
Low - 90-95% free of contaminents
Medium - 95-98% free of contaminents
High - 99% free of contaminents

(3) Deacetylation:
Low - 65%-75%
Medium - 75%-90%
High - 90%+

NOTE: Chitin is not deacetylized

4.5 Price

4.5.1 Low Grade

Establishing price/quantity relationships for low grade application is difficult as it is generally not possible to identify precisely the competing products which chitin would displace and their corresponding prices. There has been some research done on coagulating agents[1], where it was found that, in 1976, the competing polymers to chitosan sold in the $1.50 per pound range while chitosan then was selling at $2.12 to $2.72 per pound. In our interviews it was suggested that the threshold price today is probably $3.00. One respondent indicated he would buy "all we could supply" for $5.00 per kilogram.

The lower grades of chitin and chitosan presently sell for $4 - $6 per pound, and $6 - $8 per pound respectively. Japanese chitin prices range from $3.50 - $4.00. Protan's price for its lower grade chitin is $5 - $6 per pound, for its cosmetic grade chitosan, $5-$10 per pound, and for flocculation grade $4-$9 per pound.

A manufacturer of chitosan interested in this market would therefore need to be able to make his operation viable at that level.

4.5.2 High Grade

For most high grade applications, price is less important than quality, consistency and the ability to meet more exacting specifications. Individual contacts indicated they would pay between $15 and $50 per pound for high grade chitosan.

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1 MIT Sea Grant Program, "Industrial Prospects for chitin and protein from shellfish wastes".

In Exhibit 6 below, prices of chitin and chitosan currently on the market are shown.

EXHIBIT 6: CHITIN AND CHITOSAN PRICES

Low Grades	Chitin	Chitosan
Japanese	$3.50-4.00	
Protan (cosmetic grade)		$5.00-10.00
(flocculation grade)		$4.00-9.00

4.5.3 Ultra-High Grade

Ultra-high grade prices for chitin and chitosan can be as high as $2000.00 per pound. One source has indicated that the qualtiy of chitin required for making surgical sutures could attract a price of $500.00 per pound. Protan is now manufacturing ultra-high grade chitosan (on a laboratory basis), which sells for $3-$5 per gram. Sigma chemicals, a U.S. chemical distributor, buy a practical grade chitin for $7.50 per pound and re-process[1] it to produce an ultra-pure grade product which retails for $650.00 per pound. The specific process used by Sigma provides a purified chitin powder suitable for the analysis of different enzymes. Contacts at Sigma have indicated that sales of ultra-high grade chitin purchase is very low and is purchased in very small quantities (normally by the gram).

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1 The process used by Sigma is publised in: Archives of Bio Chemistry and Bio Physics, Volume III, p.358, 1965.

4.6 Market Size and Market Potential

4.6.1 Existing Market

We estimate that the total world market for lower grade chitin and chitosan is presently approximately 1,075 tonnes per year. Higher grade chitin is produced from this basic material and therefore is included in the total market estimate. Present sales of high grade chitin are virtually non-existent. All distributors have indicated that they sell almost no high grade product.

Exhibit 7 shows the market by country and application. The rate at which chitin is able to penetrate the U.S. market for these applications depends on price and satisfactorily addressing concerns about the human consumption of the material. There should be a steady growth in these applications. A doubling of the total market by 1992 is not unrealistic.

EXHIBIT 7: ESTIMATED WORLD CHITIN & CHITOSAN MARKET BY AREA AND USE
(Tonnes)

Consumption (MT's)	Total	Wastewater Treatment	Seed Coating	Clarification	Cosmetics	Research Purposes
Japan	900	850	-	-	-	50
U.S.	75	40	10	-	-	25
Europe	50	10	-	10	10	20
Other	50	-	-	-	-	-
TOTAL	1075	900	10	10	10	95

Source: DPA estimates

In addition to this, there is the market for "Clandosan". We have excluded "Clandosan" from the above table because, while it contains chitin, it is not refined to the level of extracting chitin in its pure form. "Clandosan" contains both chitin and protein.

Over the next five years, we anticipate that the existing markets can be expected to grow conservatively at a rate of 5% per year. If major new developments occur such as achieving regulatory approval in the case of wastewater, or lower prices the market could be substantially greater.

4.6.2 Short Term Developments

Market estimates for other products become much more speculative since the rate of penetration and product development cannot be predicted with any degree of accuracy. However, we believe that new applications should result in only a small increase in the market over the next two to five years (up to 100 tonnes maximum). It should increase significantly after that as these products gain more widespread acceptance. It is important to note that while there will probably be new products developed, these will all have a relatively small impact on the market for chitin or chitosan in the next five years.

In Exhibit 8, we provide estimates of the market by application to the year 1992. These estimates show both "optimistic" and "pessimistic" projections for each application. These scenarios are based on assumptions about the potential for suppliers to increase production capacity, reduce costs and obtain regulatory approaches for products now in the review process.

EXHIBIT 8: DEMAND FORECAST BY APPLICATION, TO 1992 (tonnes)

	Market 1987	Market 1992 Pessimistic	Optimistic
Existing Uses			
Wastewater	900	1,100	2,500
Seed Coating/ fungicide	10	50	200
Beverage Clarification	10	10	50
Cosmetics	10	15	30
Research	95	150	200
New Development			
Sutures	--	0	5
Dressings	--	0	10
Ointments	--	0	10
Fruit & Vegetables Preservation	--	50	100
TOTAL	1,025	1,375	3,105

Exhibits 9 and 10 show the distribution of markets by country to 1992 under the pessimistic and optimistic scenarios.

EXHIBIT 9: DEMAND FORECAST BY REGION - PESSIMISTIC FORECAST

Existing Uses	Total	Japan	North America	Europe	Other
Waste water	1100	1000	70	30	--
Seed coating/ fungicide	50	10	40	--	--
Beverage clarification	10	--	--	10	--
Cosmetics	15	--	5	10	--
Research	150	80	35	25	10
New Developments					
Sutures	0	--	--	--	--
Dressings	0	--	--	--	--
Ointments	0	--	--	--	--
Fruit & vegetable preservatives	50	--	50	--	--
TOTAL	1375	1090	200	75	10
% of Market		79	15	5	1

EXHIBIT 10: DEMAND FORECAST BY REGION - OPTIMISTIC FORECAST

Existing Uses	Total	Japan	North America	Europe	Other
Waste water	2500	1900	400	200	--
Seed coating/ fungicide	200	35	150	15	--
Beverage clarification	50	15	5	30	--
Cosmetics	30	3	7	20	--
Research	200	100	50	30	20
New Developments					
Sutures	5	5	--	--	--
Dressings	10	5	5	--	--
Ointments	10	5	5	--	--
Fruit & vegetable preservatives	100	20	70	10	--
TOTAL	3105	2088	692	305	20
% of Market		67	22	10	1

4.6.3 Longer Term Developments (6 - 10 years)

Most of the applications which will create significant long term markets for chitin and chitosan are in this category. For example, use in animal feeds and food thickeners can easily result in demand in the thousands of tonnes if chitosan can be produced at a price which is competitive with the existing competing products. These markets have to be considered very tentative at this time because of the years of development and clinical trials ahead and the concerns about price. Most researchers feel that with current technology, it is too costly to produce chitin products which can compete effectively with synthetic polymers and resins. To the extent that new, cheaper processes can be developed, there will be some major opportunities in these applications ten years hence.

Potentially, this market could be as large as 50,000 tonnes by the turn of the century. However, it is also possible that new developments will be much slower to take off than the industry now predicts and growth will remain at its historic rate of five percent per year. Looking back at the MIT study done in 1976, almost all of the applications identified as good potential still have not bee commercialized.

We believe that the next decade should be much more optimistic than the past ten years. Many more products are actually at the clinical trial or pilot plant stage and there is more confidence about the potential of these applications to actually be introduced to the market.

As we have mentioned several times, it is the individual applications which will be important in the future. Predicting what will develop for each application is entirely a speculative exercise at this point. Each needs to be separately monitored on a regular basis to be able to predict the future demand with any degree of confidence.

4.7 Regulatory Approval

The use of chitin and chitosan derivatives for human food consumption requires a very high purity level. Researchers have found that only concentration levels above 18 grams of chitosan per kilogram of body weight/day were harmful to animals. It is expected that a similar result would occur with humans. Experiments on animals have revealed that a quantity of 5% of dietary chitosan results in no difference in growth rates, inner organs or blood syrim composition. Enhanced nutritional value was also discovered from these products. With the exception of beverage clarification, the uses of chitin and chitosan in food is still in experimental stages. Regulatory approval for chitin's widespread use in food applications is anticipated to be 5 to 10 years. The reasons for this long range outlook are:

- Regulatory approval has not yet been granted by the FDA because the properties of chitin and chitosan vary with each source and very little information is known about its effect on human metabolism. It must be proven that the chemical produces absolutely no side effects before regulatory approval is granted;

- Major food companies, which represent the largest potential market, will not begin experimenting with a product until it has been approved by health authorities;

- The cost to register a new food product in the U.S. can be as high as five million dollars. The average approval costs for food additives alone is $500,000. Thus, a company must conduct expensive experiments to prove its non-toxicity, usefulness and/or benefits before spending this amount of money. Canada

is presently averaging between $200,000 to $300,000, for new food registration.

Costs are high but companies do persist where the potential appears attractive. European Health Officials have now approved chitosan use as a clarifying agent for beer and wine manufacturing.

4.8 Conclusions

The current market for chitin and chitosan is limited and worldwide production is substantially below capacity. In a general market overview such as this, it is difficult to quantify where opportunities lie because each application is different.

The main barrier to greater market development in the high-volume, lower quality material is the high price of chitin relative to other synthetic materials. If production costs can be lowered to be competitive, the market would open substantially.

In the medium to long term, the outlook is much more optimistic. Several new products will come into commercialization. These products do not require high volumes of chitin, but they require a very high quality developed to exacting specifications. These opportunities will open markets for "niche players" who are prepared, or have special processes, to meet the requirements of pharmaceuticals and medical applications which are likely to be on the market in the short to medium term.

Market development costs are high relative to the profit margins on chitin and chitosan. Any new producers will probably enter the market by forming tie-ins with: large chemical companies (who already have good marketing networks in fields such as waste treatment); chitin producers in other areas such as Japan where obtaining an adequate supply of raw materials is a problem; or companies involved in processing chitin and chitosan into higher grade products. Some of these approaches may be used in

combination. For example, a producer could make a line of basic chitin, possibly distributed by a chemical company, and have a specialized production process for supplying one particular customer with chitosan meeting certain precise standards.

With low prices and a saturated market, a high quality product is needed to generate profits to allow volume production to take place on lower quality chitin and chitosan.

5.0 CHITIN PRODUCTION IN NEW BRUNSWICK

Although not specifically included in our mandate for this study, there are a number of observations which are relevant to the possibility of chitin and chitosan production in New Brunswick and we report on these in this chapter.

5.1 Raw Material Supply

5.1.1 Quality

It has been stated that the quality of New Brunswick crab waste (see Appendix D for details on the characteristics of chitin/chitosan by raw material source) is not well suited to ultra-high grade applications. The amount of harsh chemical treatment required to produce chitin affects the quality of the resulting product. Another limitation is the ability of producers to store and transport wastes. Highest grades of chitin are achieved when the product is fresh and wet.

A contrary opinion was also expressed by one study contact who believed that ultra-high grade chitin could be produced. He did however, acknowledge that extensive research into production techniques would be required.

While various processes have been tried at bench scale, no pilot processing plant has been developed in New Brunswick. A pilot plant is probably the only way to determine with any confidence the potential level of quality obtainable.

5.1.2 Quantity

The supply of raw materials in New Brunswick appears adequate in theory to support a small chitin industry. A kilogram of chitin requires 12 kilograms of wet waste, and most plants producing low quality chitin are built to handle an output of the order of 300 - 500 tonnes per year.

Total crab landings in 1985 amounted to 17,000 tonnes. Wet wastes are approximately 65% of landings and chitin comprises 8% of this waste. The total theoretical chitin production therefore is of the order of 900 tonnes.

However, using all the crab waste for chitin production would appear unrealistic for several reasons:

- geographical location of suppliers;
- the seasonality of the fishing industry;
- lack of facilities to dry or freeze the raw material; and
- transportation and storage costs.

A more realistic estimate of the amount of chitin that could be processed in New Brunswick is probably in the order of 250-300 tonnes.

Based on our understanding of the industry, a facility producing only 250 tonnes of chitin would probably have to focus on obtaining the highest grade possible, as profitability will need to depend on high profit margins rather than a low margin/high volume strategy.

To put the New Brunswick supply in perspective, the following is a comparison of the supply of wet shellfish wastes in areas of the U.S. where there are chitin processors or where plans are being made to establish a processing facility:

State of Washington (Protan)	10,180 Tonnes
New Brunswick (1985)	**11,140 Tonnes**
State of Oregon (Bentech)	12,480 Tonnes
Texas-Gulf Region (Chitin Co., Kynek)	35,900 Tonnes
New England Region (Chitin Co.)	39,877 Tonnes
Chesapeake Region (Chitin Co., Iogene)	46,180 Tonnes

New Brunswick is at the lower end of this list, but Washington, which is at the bottom, is actually the only area of the U.S. now supporting an active chitin producer. Estimates of chitinaceous material supply for various parts of the world are provided in Appendix E.

5.2 Interest in New Brunswick Joint Venture

During the course of the study several companies expressed an interest in becoming involved with chitin/chitosan production in New Brunswick.

Protan

Protan has suggested it would be interested in having a New Brunswick contact act as distributor for Protan's products and to develop, with Protan's help, specific market niches for their products. Protan would then be prepared to joint venture with a New Brunswick company in establishing a manufacturing facility once market demand exceeds Protan's present capacity. Protan's management believes that it would be very difficult for a new company to compete in the market at this time.

Bentech Laboratories Inc.

Bentech officials are interested in a possible link up with a New Brunswick manufacturing facility. However, their first priority would be to test the quality and consistency of the product produced. If tests were favorable they would consider being involved in a new facility.

Chitin Company

The volume of crab shells available in New Brunswick and the close geographical proximity to their Boston operation has produced great interest from the Chitin Company in a plant in New Brunswick. The company would probably establish its own plant and have the fish processors provide them with waste. Company

officials have indicated that they are prepared to begin negotiations very soon, and asked us to request meetings with any interested parties. Mr. Don Lambardi, a company principal, feels this would be beneficial to both parties involved, in that it would alleviate the present shellfish disposal problem in New Brunswick while providing an abundant supply of raw materials to their company.

Farrson Chemicals

Mr. Frepons, manager of Farrson chemicals has indicated he would be very interested in speaking with New Brunswick officials regarding the possibility of a joint venture or an exclusive supply contract agreement. Mr. Frepons believes that if sales go as planned, Farrson Chemicals would be able to purchase all the chitosan that the province of New Brunswick could provide.

Nova Chem

Mr. Don Davies, owner of Nova Chem has stated that their company would be prepared to joint venture with a New Brunswick operation to assist in Nova Chem's long term plans.

Hosho Summerset

Mr. Michael Mau, company manager, has indicated that he is interested in a possible joint venture for a new facility.

Kytek

Company management has indicated that if sales go as planned for Kytek their company would be very interested in New Brunswick. The company anticipates that it may not be able to meet market demand within the next 5 years and will be looking for an additional source.

5.3 Strategic Options

Based on our analysis of the market, and without specific production or cost of operations data, we believe there are four the possible strategies for someone interested in chitin production in New Brunswick. These are summarized in Exhibit 11.

We believe that the only viable approach is through joint venturing with an established and credible company focusing on high grade products. A producer entering "on spec" to produce low grade chitin will have so many barriers, not the least of which is not knowing what the potential of the raw material is, that he would be very unlikely to attain viability.

Attempting to set up a plant to make chitin or chitosan to meet one specific market niche is risky. The new producers would be dependent on the success of the customer for viability, and the customer could change suppliers at a future date.

Vertically integrating (i.e. producing chitin or chitosan and processing it into a finished product such as fruit and vegetable coating) is the fourth possible approach. This has been abandoned by most who have tried it as their energies become split between the two products. They tend to find it preferable to buying the raw material in the rawest form possible, and then concentrate on processing.

The joint venture between Connors Bros. and Nippon Suison is an example of the most effective strategy for addressing this opportunity. A joint venture will afford the chance to learn about the process, make an investment in a pilot plant to determine the potential of the resource and use an established distribution network to handle sales of the product.

The learning process will take place when the market is still developing. By the time the major opportunities come on stream, the local producer would be in a better position to determine the

needs of each of the markets and develop the best strategy for filling them.

EXHIBIT 11: OPTIONS AVAILABLE FOR A NEW BRUNSWICK PRODUCER

OPTION	STRENGTHS	WEAKNESSES	COMMENTS
1. Low grade chitin production	- lower costs - opportunity to develop expertise for later improvements	- volume appears insufficient for profitability - price/cost relationship not favorable - competition is well entrenched	- not recommended
2. Joint venture with company with proven market or use	- market is established - technical assistance from partners	- may be excluded from other markets - control of the enterprise?	- probably most viable
3. Supply to a user of high-grade chitin	- market is established - more independence - technical assistance	- vulnerable to market conditions of purchasers - problems if unable to meet quality standards on an on-going basis - high capital costs	- not recommended
4. Vertical integration (go from waste to production of a high grade end product)	- quality control - sure source of supply	- need to find an application to purchase or license - would have to bear costs of regulatory approval	- could work if a local processor has patents or licenses

APPENDIX A

CONTACTS

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R.A. Smucker Chesapeake Biological Lab University of Maryland Solomans, Maryland, USA (301) 326-4281	Biomedical application
S.S. Stivala Chemical Engineer Stevens Institute of Technology Hoboken, New Jersey USA (201) 420-5528	Blood anticoagulant

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Chitosan effects on human consumption

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Cholestrol reduction agent
blood anticoagulant

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APPENDIX B

PRODUCT SPECIFICATION AND PRICE LIST

PROTAN

PROTAN

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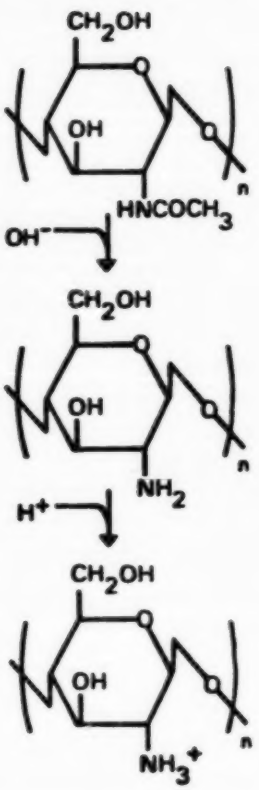
CHITIN AND CHITOSAN -- GENERAL PROPERTIES AND APPLICATIONS



CHITIN

-- the natural structural component of the shellfish--crab, shrimp, and lobster
-- second most plentiful natural polymer next to cellulose
-- biodegradable, non-toxic

CHITOSAN-POLYAMINE

-- high molecular weight
-- soluble in most dilute acidic solutions
-- polyamine
-- biodegradable, nontoxic
-- insoluble at pH's above 6.5

CHITOSAN-CATIONIC

-- high charge (positive) density
-- compatible with strong cationics
-- forms strong, clear films
-- forms clear aqueous solutions with excellent heat and shear stability
-- excellent flocculent
-- forms gels with multivalent anions
-- chelates metal ions
-- biodegradable, nontoxic
-- low to high viscosity grades available

A. Properties

	Typical Values
1. Particle size	flakes to fine powder available
2. Bulk density, g/cm^3	0.15 - 0.30
3. Moisture content, %	<10
4. Ash, % dry weight	< 2
5. Solution color	clear
6. % deacetylation	>70

B. Viscosity Grades

	1% Viscosity, mPa.S (cps)*
low	< 200
medium	200-800
high	> 800

*Brookfield LVT viscometer, 20°C, 30 rpm

Solubility in Organic Acids

- Acetic Acid -- Acetic acid is the most commonly used organic acid for solubilizing chitosan. In general chitosan is soluble if the pH is about 4.0. One percent solutions (1 g chitosan/100 ml acetic acid solution) can be made readily.

- Solubility in Other Organic Acids -- The following acidic solutions have been found useful for dissolving chitosan (1%).

SOLUBILITY (1 gm chitosan/100 ml acidic solution)

Acid Concentration	1%	5%	10%	50%	>50%
Acetic	+	+	+	±	
Adipic	+				
Citric	-		+		
Formic	+	+	+	+	+
Lactic	+	+	+		
Malic	+	+	+		
Malonic	+	+	+		
Oxalic	-		+		
Propionic	+	+	+	+	
Pyruvic	+	+	+		
Succinic	+	+	+		
Tartaric	-		+		

Solubility in Inorganic Acids

- HCl/HNO_3 -- Chitosan is soluble in the range of 0.15 to 1.1%, but is insoluble in 10% acid solutions.

- H_2SO_4 -- Chitosan is not soluble at any concentration.

- H_3PO_4 -- Chitosan is not soluble in 1% H_3PO_4, and is only marginally soluble at 0.5% concentrations.

Preparing Chitosan Solutions

Chitosan is not soluble at pH's above 7.0; therefore, to avoid precipitation, the pH must be maintained at pH 6.0 or below.

The preferred method to make a 1% solution is to slurry the chitosan in water (e.g., 2 gm/100 ml) then add an equal volume of a 2% solution of the desired organic acid (e.g., 100 ml, 2% acetic acid). The resulting mixture, now 1% in chitosan and 1% in acid, should be stirred vigorously for 60 minutes or until complete solubility is realized. Heating the solution can accelerate the process, but prolonged heating in acid can result in loss of viscosity. Alternatively, chitosan can be dissolved directly by adding chitosan to a prepared solution of acid.

Viscosity Determination

For comparative purposes, acetic acid is used as the standard solvent.

For a 1% solution, disperse 2 g (dry basis) of chitosan in 100 ml of distilled/deionized water, and with agitation, add 100 ml of 2% (2 g/100 ml) acetic acid. Stir for 60 minutes or until dissolved. Viscosity is measured with a Brookfield LVT viscometer, 20°C, 30 rpm, appropriate spindle, two hours after dissolution.

Compatibilities

Cationics

- Cationic dyes (e.g., methylene blue)	compatible
- Quarternary ammonium salts	"
- Cationic surfactants	"
- Cationic starches	"
- Cationic latices	"

Nonionics

- Most polymers	compatible

Anionics

- Most anionic polymers	incompatible, form gels

APPLICATION	FUNCTION OF CHITOSAN
1. CLARIFICATION	
- food processing waste streams	- flocculate/coagulate proteins/lower BOD
- fruit juices	- flocculate pectins/proteins
- wine/fermented beverages	- flocculate proteins/microbes
- drinking water	- coagulant
- swimming pools/spas	- flocculate microbes/remove metals
- gravel wash	- flocculate colloidal clays
- remove dyes	- form insoluble complex with anionic dyes
- remove tanins	- form complex with polyphenolics
2. RECOVERY OF PROTEIN	
- AAFCO/FDA approved for animal feed (<0.1%)	- precipitate proteinaceous material from waste streams
- algae for feed	- flocculate/dewater
3. DETOXIFY INDUSTRIAL WASTE STREAMS	
- remove toxic metals	- chelation of metal ions (e.g., Hg, Cd, Pb)
- remove toxic metals, chemicals	- form complexes (e.g., dyes, tannins, PCB)
4. IMMOBILIZE ENZYMES/ LIVING CELLS	- gel immobilization matrix - increase stability, compatible with phosphates
5. PERSONAL CARE PRODUCTS	
- hair care	- substantive to hair
- skin care	- form clear protective coating, moisture retention
- viscosifier	- build viscosity in amphoteric/ nonionic shampoos
- cosmetics	- viscosity building, coating, moisture retention, nonallergenic
6. BIOMEDICAL	
- lower cholesterol	- anticholesteric
- wound care	- accelerate wound healing
- eye bandages	- forms tough protective coating, biodegradable

- drug delivery	- bioerodable, non-toxic
- contact lens	- crosslinked to give porous, "grindable" lens material, nonallergenic
- dental	- bioadhesive
- absorbable sutures	- biodegradable
- orthopedic	- temporary bioeng. material

7. BIOTECHNOLOGY

- immobilized enzymes	- complexes with proteins
- immobilized living cells	- forms gel matrix (e.g. beads)
- encapsulate cells	- replace polylysine in algin bead process
- filtration	- membranes can be cast, film forms
- recover valuable protein	- complexes with protein, flocculate
- chromotography	- support enzymes/cells

8. TEXTILES/PAPER

- coat textiles	- water repellent
- nonwoven fabrics	- improved wet and dry strength
- binder for paper	- film former
- coat paper	- wet and dry strength additive
- retention aid	- bind clays, cellulose

9. AGRICULTURE

- coat seeds (wheat, peas, rice)	- fungistatic, protect crop, increase yields
	- retain moisture, nutrients
- slow release agent	- encapsulate

10. COATINGS

- violin varnish	- dry hard, good tone
- water proofing	- bind surface

11. ADHESIVES

- paper	- film formation, adhesive
- wood	- adhere to lignin, cellulose

12. PHOTOGRAPHY

- film	- lower silver density
	- fixative
	- coating

13. EMULSIONS

- stabilizer
- breaker
- viscosity builder
- coagulate anionic emulsion stabilizers

Product Safety

LD_{50} (mice, orally)

LD_{50} > 16 gram per kilogram body weight according to Arai et al (Bull. Tokai Regional Fisheries Res. Lab., No. 56, 1968), "the LD_{50} values for chitosan are nearly 1/10th those for copolymers acrylamide and methacrylate and are of the same order of magnitude as lethal doses of sugar (sucrose) or salt (NaCl)."

Potable Water

According to the U.S. Environmental Protection Agency, chitosan is acceptable for potable water applications when used within the stated rates and under the restrictions listed:

1. A bed of flaked chitosan may also be used as filter medium in potable water treatment.

2. Whereas deacetylated chitin is newly proposed as a potable water treatment chemical, and whereas such new chemicals do not fulfill the requirement of "virtual identity" in FR 44, No. 141, below, chitosan is acceptable for use only on an experimental or pilot basis, under conditions which are carefully controlled by the appropriate State.

3. The Office of Drinking Water (ODW) is interested in chitosan pilot studies. ODW requests to be kept informed of the progress and results of such studies, which will be made part of the product file and will eventually mitigate any restrictions on its use.

Animal Feed

In conjuction with the Division of Animal Feeds, Department of Health and Human Services, U.S. Food and Drug Administration (FDA), The Association of Animal Feed Control Officials, Inc. (AAFCO), has issued the following description of chitosan:

"Chitosan is a cationic carbohydrate polymer intended for use as a precipitating agent of proteinaceous material from food processing plants. It is chemically derived by deacetylation of

the naturally occuring chitin in crab and shrimp shells. It may be used in an amount not to exceed that necessary to accomplish its intended effect. Chitosan when fed as a component of feed to livestock shall be present at no more than 0.1% of the feed. Proteinaceous material coagulated with chitosan must have safety and efficacy data approved before it can be registered or offered for sale." (Proposed 1984, Adopted 1985)

Biodegradability

Enzyme degradation - Chitin and chitosan-degrading enzymes have been found in bacteria, fungi, algae, fish, reptiles, birds and mammals. Essentially there are three groups of enzymes; chitinases, chitosanases and lysozymes, that degrade chitinaceous materials.

COD - Shrimp chitin 1.24 mg O_2/mg organic matter (Pollution Abatement and By-Product Recovery in Shellfish and Fisheries Processing, Water Pollution Control Research Series Project #12130 FJO, June 1971).

DISCLAIMER: What is said in this brochure is not to be taken as a warranty or representation and is offered for your consideration, investigation and verification. Information in this brochure does not grant permission or recommendation to practice a potential invention without a license. Until you have determined the safety and legality of the use, any chemical mentioned should not be used in a food, drug or cosmetic or in a product or process in which it may contact a food, drug or cosmetic. Protan's chitosan technologies are protected by U.S. Patents 3,533,940; 3,862,122; 3,922,260; 4,066,735; 4,018,678; 4,159,932; 4,195,175; 4,199,496.

Rev 1/6/87

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CHITOSAN SPECIFICATIONS

PROTASAN™ - Very high quality, ultrapure developmental product, inquire about availability

SEA CURE™ - High quality, suitable for most cosmetic, topical, biotechnology, diagnostic and enzyme immobilization

Sea Cure-F = Flake
Sea Cure-P = Powder

- moisture	≤ 10.0%
- ash	≤ 1.0%
- total insolubles	≤ 1.0%
- % deacetylation	≥ 70%

PRO FLOC™ - Industrial

Pro Floc-F = Flake
Pro Floc-P = Powder

- moisture	≤ 10.0%
- ash	≤ 3.5%
- total insolubles	≤ 2.0%
- % deacetylation	≥ 70%

Pro Floc-SD = Self-Dissolving Blend

- moisture	≤ 10.0%
- ash	≤ 2.0%
- total insolubles	≤ 3.5%
- % deacetylation	≥ 70%
- polymer intrinsic viscosity	≥ 8.0 dl/g(25°C)

VISCOSITY* GRADES

Low	< 200 mPa.S (cps)
Medium	200-800 mPa.S (cps)
High	> 800 mPa.S (cps)

*Brookfield LVT Viscometer, 30 rpm, 25°C 1% SeaCure-F/P, ProFloc-F/P in 1% Acetic Acid

PACKAGING/SHIPPING

Boxes	Pallets
40/50 lbs	640/800 lbs

GENERAL INFORMATION

1. Contact us for price information
2. Chemical analysis available on request.

rev 3/9/87

BIOSHELL

BIOSHELL, INC.
635 WATER AVENUE EAST • ALBANY, OREGON 97321 • (503) 928-4552 • TELEX: 360-141

CHITIN SPECIFICATIONS

Shape - Flat angular particles

Particle size distribution - > 35 mesh 20.8%
35-60 mesh 62.8%
60-100 mesh 10.4%
< 100 mesh 6%

Moisture 6-10 %
Ash - 0.5 % maximum
Protein - 0.5 % maximum
% Deacetylation - 16 % approx.
Bulk density - 0.25 g/cc
Heavy metals - Pb-BDL (<10 ppb)
As-BDL (<10 ppb)
Total of Ag,As,Bi,Cd,Cu,Hg,Pb,Sb
Sn less than 5 ppm

Bacteriological - Salmonella - none
Coliforms - none
Total plate count - < 10 colonies

BIOSHELL, INC.

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PRICE LIST AS OF JANUARY 1, 1984

CHITIN

Purchase Quantity	Price Per Pound
1 to 5 lbs.	$ 11.00
10 lbs.	$ 9.50
20 lbs.	$ 7.25

DRUM PRICES PACKED IN 80 LB DRUMS

Drums Purchased	Price Per Drum	Price Per Pound
1	$ 500.00	$ 6.25
5-10	$ 440.00	$ 5.50
15-20	$ 420.00	$ 5.25
25-50	$ 400.00	$ 5.00
55-100	$ 380.00	$ 4.75

CHITOSAN

Purchase Quantity	Price Per Pound
1 to 5 lbs.	$ 20.00
10 lbs.	$ 17.50
20 lbs.	$ 16.50

DRUM PRICES PACKED IN 80 LB DRUMS

Drums Purchased	Price Per Drum	Price Per Pound
1	$ 1200.00	$ 15.00
5-10	$ 1120.00	$ 14.00
15-20	$ 1000.00	$ 12.00
25-50	$ 820.00	$ 10.25
55-100	$ 780.00	$ 9.75

ALL PRICES F.O.B. ALBANY, OREGON--FREIGHT COLLECT

PRODUCTS FROM THE SEA THROUGH CHEMISTRY • CHITIN • CHITOSAN

BIOSHELL, INC.
635 WATER AVENUE EAST • ALBANY, OREGON 97321 • (503) 928-4552 • TELEX: 360-141

PRICE LIST AS OF SEPTEMBER 1, 1982

CHITIN

Purchase quantity	Price per pound
1 to 9 lbs.	$ 8.20
10 to 99 lbs.	$ 6.10
100 to 1999 lbs.	$ 5.15
1 ton and up	$ 4.75

CHITOSAN

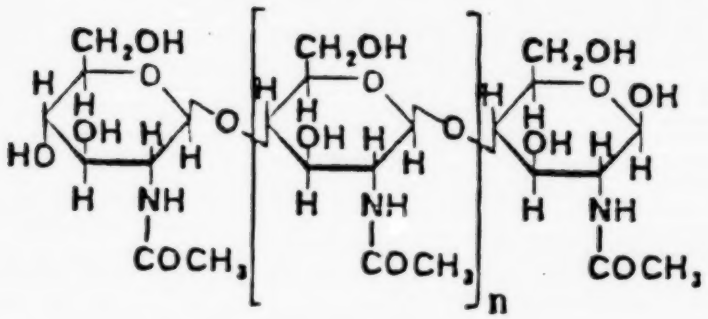
Purchase quantity	Price per pound
1 to 9 lbs.	$ 18.40
10 to 99 lbs.	$ 14.75
100 to 1999 lbs.	$ 10.15
1 ton and up	$ 9.75

All prices F.O.B. Albany, Oregon

KALAALLIT TUNISASSIORFIAT

KALAALLIT TUNISASSIORFIAT
The Production Company of the Greenland Home Rule

CHITIN



CHITIN is a polysaccharide composed of beta-1,4 - linked N-acetyl-D-glucosamine.

This chitin is produced from fresh cold water Greenlandic Prawn Shells (Pandalus borealis) by decalcification with diluted hydrochloric acid and deproteinisation with hot diluted sodium hydroxide.

Chitin is soluble in concentrated hydrochloric acid, sulphuric acid, phosphoric acid and anhydrous formic acid.
Chitin is insoluble in water, dilute acids and alkaline ethanol and organic solvents.

Rcd.
Apr. 15, 1987
Paul R. Austin

Appearence	white to greish
Degree of fineness	rough material
Moisture	10%
Ash	0.6%
Total nitrogen	6.8%
Protein	0.4%
pH	3.6.%
Heavy metals	less than 1 ppm

Assay methods NMKL and Greenland Home Rule.

Branch Office • 100 Strandgade • P.O.Box 2209 • DK-1018 Copenhagen K

SIGMA CHEMICALS

ALPHABETICAL LIST of ALL COMPOUNDS

RECOMMENDED STORAGE AS INDICATED -0°C = FREEZE 0-5°C = REFRIGERATOR RT = ROOM TEMPERATURE

PRODUCT NUMBER			$
	CHICAGO SKY BLUE 6B (pfs)	25 g	5.50
C 0392	(C.I. 24410; Direct Blue 1)	100 g	18.55
	Dye content: Approx. 50%		

CHICKEN BREAST MUSCLE ACETONE POWDER
See Muscle Acetone Powder, Chicken Breast *Page 965*

CHICKEN IgG
See Immunoglobulins in the Immunochemicals Section *Page 705*

CHICKEN LIVER ACETONE POWDER
See Liver Acetone Powder, Chicken *Page 869*

CHICKEN PROTEINS, Antisera to
See Immunochemicals Section *Page 705*

CHIMYL ALCOHOL
See 1-O-Hexadecyl-rac-glycerol *Page 857*

CHIRALD™
See (2S,3R)-(+)-Dimethylamino-1,2-diphenyl-3-methyl-2-butanol *Page 527*

CHIRALPLATE®
See Chromatography Section.

CHITIN
(Poly-N-acetylglucosamine)
From Crab Shells

	Purified powder	250 mg	8.20
C 3641	Suitable for analysis of	1 g	22.80
	chitinase.	5 g	75.90
	Purified from C 3132 by the method of Skujins, J.J., et al., Arch. Biochem. Biophys., 111, 358 (1965).		
C 3132	**Practical Grade (pfs)**	100 g	3.35
	Coarse flakes.	500 g	10.10
		1 kg	16.80
		FOB Sigma	
C 3387	**Practical Grade**	10 g	3.55
	Powder	100 g	7.05
	Requires purification prior to use as a substrate for chitinase.	1 kg	35.55
		FOB Sigma	
	Ref.: Skujins, J.J., et al., Arch. Biochem. Biophys., 111, 358 (1965).		

CHITINASE
(Chitodextrinase; Poly[1,4-β-(2-acetamido-2-deoxy-D-glucoside)]-glycanohydrolase; EC 3.2.1.14)
Unit Definition: One unit will liberate 1.0 mg of N-acetyl-D-glucosamine from chitin in 48 hours at pH 6.0 at 25°C. (N-acetyl-D-glucosamine is measured using 3,5-dinitrosalicylic acid reagent).

	From Serratia	25 units	6.60
C 1650	**marcescens**	50 units	10.85
	Lyophilized	250 units	36.10
	powder	500 units	60.20
	containing approx. 15% protein (Biuret); balance phosphate buffer salts.		
	Activity: 1-3 units per mg solid.		
	From Streptomyces	25 units	6.75
C 6137	**griseus**	50 units	11.25
	Lyophilized	250 units	37.00
	crude powder	500 units	66.60
	containing approx. 20% protein (Biuret).	2,500 units	263.75
	Activity: 2-3 units per mg solid.		

(Continued)

PRODUCT NUMBER			$
	(Continuation of) **CHITINASE**		
	From Streptomyces	10 units	7.05
C 1525	**griseus**	25 units	14.10
	Lyophilized	50 units	23.50
	powder	100 units	41.60
	containing approx. 60% protein (Biuret); balance phosphate buffer salts.		
	Activity: 10-15 units per mg solid.		
	CHITIN AZURE	100 mg	6.70
C 3020	A substrate for chitinase	250 mg	13.40
	Chitin, from crab shells, C 3387	1 g	37.10
	covalently linked with Remazol	5 g	123.65
	Brilliant Violet 5R (RBV) dye.		
	Ref.: Hackman, R.H. and Goldberg, M., Anal. Biochem., 8, 397 (1964).		

CHITOBIOSE
See N,N'-Diacetylchitobiose *Page 493*

CHITOSAN

C 3646	**Practical Grade (pfs)**	10 g	4.30
	From Crab Shells	25 g	8.45
		100 g	26.95
C 2263	**From Shrimp Shells**		Inquire

CHITOTRIOSE
See N,N',N''-Triacetylchitotriose *Page 1347*

CHLORAL HYDRATE

C 8383	**Crystalline (pfs)**	100 g	6.85
	Telephone and telegraph orders not accepted.	250 g	12.10
		1 kg	39.75
	See pages 3 and 4 for additional ordering information.	FOB Sigma	
	See also Controlled Substances *Page 437*		
	Methanol solution - 1 mg per ml	1 ml	14.00
C 6516	Sealed ampule.	FOB Sigma	
	See also Drug Standards in the Standards and Controls Section.		

	α-CHLORALOSE (pfs)	10 g	3.40
C 0128	(1,2-O-[2,2,2-Trichloroethylidene]-α-D-glucofuranose)	25 g	4.90
		100 g	12.00
	Contains approx. 10% β-isomer.	1 kg	105.00
		FOB Sigma	
	β-CHLORALOSE (pfs)	100 g	11.60
C 9384		500 g	38.65

	CHLORAMBUCIL (pfs)	100 mg	4.25
C 0253	(4-[p-[bis[2-chloroethyl]amino]-phenyl]butyric acid)	500 mg	9.00
		1 g	12.30
	Possibly Carcinogenic.	10 g	110.70

	CHLORAMINE B (pfs)	100 g	7.35
C 2279	(N-Chlorobenzenesulfonamide, sodium salt)	500 g	27.20
	Hydrate		

	CHLORAMINE T (pfs)	250 g	8.20
C 9887	(N-Chloro-p-toluenesulfonamide, sodium salt)	500 g	14.75
		1 kg	20.50
	Trihydrate	FOB Sigma	
	Crystalline		

APPENDIX C

U.S. DISTRIBUTORS

U.S. DISTRIBUTION OF CHITIN AND CHITOSAN

Hercules Inc, Wilmington

* Lanze Warring
* Mark Ross
Sigma Chemicals Co.

Phanstiehl Laboratories

J.T. Baker

Schuchosdt

Eastman Organic Chemicals

ICN Pharmaceuticals

K.E.I.

P.L. BioChemicals

Polyscience Inc.

Calbiochem

Kypro Co.

* Dr. Lou
C.T.C. Organics

International Industrieal Enzymes

Pacific Chemical Laboratories

APPENDIX D

CHITIN CONTENT PER RAW MATERIAL SOURCE

CHITIN CONTENT *of selected crustacea, insects, molluscan organs, and fungi (Kong, 1975; Naczk et al., 1981)*

Type	Chitin Content (%)	Type	Chitin Content (%)
Crustacea		**Insects** *(continued)*	
Cancer (crab)	72.1[c]	May beetle	16[b]
Carcinus (crab)	0.4–3.3[a]	Diptera (true fly)	54.8[c]
	8.29[b]	Pieris (sulfur butterfly)	64[c]
	64.2[c]	Grasshopper	2–4[a]
			20[c]
Paralithodes (King crab)	35[b]	Bombyx (silkworm)	44.2[c]
Callinectes (blue crab)	14[a]	Calleria (wax worm)	33.7[c]
Pleuroncodes (red crab)	1.3–1.8[b]	**Molluscan Organs**	
Crangon (shrimp)	5.8[b]	Clamshell	6.1
	69.1[c]	Oyster shell	3.6
Alaskan shrimp	28[d]	Squid, skeletalpen	41.0
Nephrops (lobster)	69.8[c]	Krill, deproteinized shell	40.2 ± 5.2
	6.7[b]		
Homarus (lobster)	60.8–77.0[c]	**Fungi**	
Lepas (barnacles)	58.3[c]	Aspergillus niger	42.0[e]
		Penicillium notatum	18.5[e]
Insects		Penicillium chrysogenium	20.1[e]
Periplaneta (cockroach)	2.0[a]	Saccharomyces cerevisiae (bakers yeast)	2.9[e]
Blatella (cockroach)	18.4[c]	Mucor rouxii	44.5
	10[b]	Lactarius vellereus (mushroom)	19.0
	35[c]		
Colcoptera (beetle)	5–15[b]		
	27–35[c]		
Tenebrio (beetle)	2.1[a]		
	4.9[b]		
	31.3[c]		

[a]Wet body weight
[b]Dry body weight
[c]Organic weight of cuticle
[d]Total dry weight of cuticle
[e]Dry weight of the cell wall

SOURCE: ARTICLE FROM FOOD TECHNOLOGY, JANUARY1984

APPENDIX E

GLOBAL ESTIMATES OF CHITINACEOUS MATERIALS

Global Estimates of Annually Accessible Chitinaceous Materials as Potential Chitin Sources[a]

Chitin Resource	Quantity Harvested[b]	Chitinaceous Waste: As Fraction of Harvest (percent)	Chitinaceous Waste: Wet Weight	Chitinaceous Waste: Solids Content (percent)	Chitinaceous Waste: Dry Weight	Chitin Potential[c]	References
Shellfish[d,e]	1,700	50-60	468	30-35	154	39	(24,37)
Krill[f]	18,200	40	3,640	22	801	56	(23,31,36)
Clam/Oysters[e]	1,390	65-85	521	90-95	482	22	(8,24,30)
Squid[e,g]	660	20-40	99	21	21	1	(3,11,24,30)
Fungi[h]	790	100	790	20-26	182	32	(12,21,26,33)
Insects	negligible	---	---	21-56	---	--	(52)
Total	22,740		5,118		1,640	150	

[a]Estimates are based upon mean values and are given in kilotons.

[b]It is assumed that only half of the harvested organisms are processed, except for fungi where the entire production is already processed for the principal product of the fermentation.

[c]Calculated using mean chitin content values listed in Table 2.

[d]Shellfish comprises crab, shrimp, prawn, lobster and crayfish.

[e]Five-year (1970-1974) average landings.

[f]FAO (Rome) projection of potential landings (23).

[g]Calculated on the assumption that the pen is 50% water.

[h]By-products of citric acid and antibiotic manufacture; it is assumed that the quantity of citric acid and its mycelium are equivalent (26), antibiotic waste is 50% nonfungal (21) and world production is twice that of the U.S. (21).

SOURCE: ARTICLE FROM FOOD TECHNOLOGY, JANUARY, 1984